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THE INTERNATIONAL SOCIETY OF CERTIFIED ELECTRONICS TECHNICIANS

STUDY GUIDE FOR THE ASSOCIATE LEVEL CET TEST

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Edited by
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5th Edition

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Reinforcement for the Study Guide for the Associate Level CET Test, 5e – As of Sept. 15, 2010

The following suggestions have come to us and we at ISCET believe these explanations and clarifications will help you in your pursuit of Associate Certification. We offer this information not as an edit or errata for this study guide but rather as an ISCET opinion and for content reinforcement.

Page:

2-1 Today a five-ban precision resistor code is more likely to be seen than the one with the reliability code. The first three bands represent the 1st, 2nd, and 3rd digits. The 4th band specifies the multiplier, the multiplier is the number of zeros to add to the end of the first three digits. A 4th band of brown would mean multiply by 10 or add one zero while a silver band means multiply the value given in the first three digits by 10^{-2} or 0.01. Gold means to multiply by 10^{-1} or 0.1. The 5th band signifies a tolerance of ±2% or less. Red= ± 2%, brown= ± 1%, green = ± 0.5%, blue = ± 0.25% and violet = ± 0.1%.

2-2 In the second paragraph, it is suggested that most common resistor is the carbon composition. In the older equipment, still in use today, you will find that to be true but with the advent of new technologies; other types may now prevail. In the last paragraph the color code for 10 Ω would be brown, black, black (one-zero- no zeroes).

2-9 The value of R30 is given as 0.1 Ω. Since R stands for a decimal, the value would be 0.3 Ω.

4-3 To be consistent with the given value of R_1, the value used as the dividend in the formula should be 10 and not 30 as shown. In the follow-through calculation the dividend used was 10 so the answer is correct.

8-1 The next to last paragraph might cause some confusion so it would be best if ignored.

8-4 The first two lines should be stricken as they are repeated from the previous page. In the third complete paragraph, third from the last sentence, the end of the sentence should read "…and plug which is plugged in to the equipment." In the third from last paragraph, first sentence, the word "color" should not be used after the word "AC".

8-5A In the second paragraph, at the end of the second sentence the "1" should be expunged.

8-7 The 16th line should read "In the range from 0.5 msec/DIV up to 0.5 Microsecond/DIV,…"

10-3 The second question comes from an old troubleshooting procedure used by technicians to get a quick idea if the DC parameters are correct in both unipolar (JFET) and bipolar (Bipolar Junction Transistor, BJCT) class A Amplifier circuits. Once one determines a reason to suspect a stage, and after measuring the supply to that circuit, the technician will measure the DC voltage and the Drain (JFET) or Collector (BJT). It normally would be about one-half of the supply voltage but usually not exactly because there are other circuit or design considerations. This why the correct answer says, "**About** one-half the supply voltage". The choice number 2 is the best answer of the three and is qualified by the word **about.** This test gives an excellent insight to the operational capabilities of the circuit, providing, or course, that the technician fully understands semiconductor theory.

PREFACE

WHAT DOES CERTIFICATION MEAN TO YOU?

In all probability you are using this Study Guide in preparation to sit for the ISCET Associate CET Certification.

Congratulations on your decision. Certification is required by some government agencies and some large companies as a condition of employment...but there are not the numbers of jobs at stake by these requirements to account for the number of certifications currently in place...and those yet to occur.

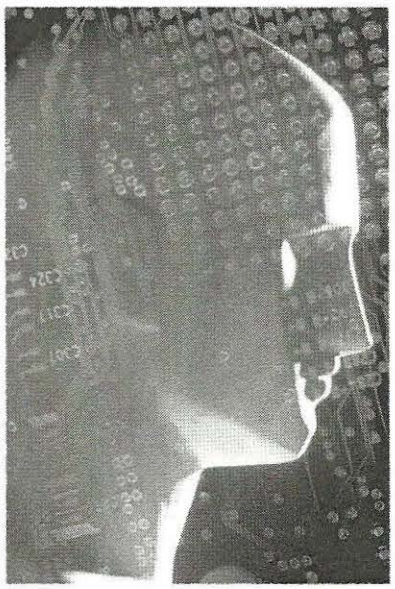
What is evident is the fact that when you are certified, just a little more effort, investment and time are involved. Your decision to start on the road to certification indicates that you understand the benefits to you after earning Certification. It will distinguish you from others by saying that you have conquered the fear that tugs at you by the specter of failure.

All of us do, from time to time, neglect to take steps towards advancement because we fear that we might, for some reason, not measure-up. Once you have conquered this hesitation by seeing that the more compelling achievement is to continue to climb that ladder to success that is only trod by those who think constantly about how they can achieve their goals...success and self esteem that follows the person that trods the path of self betterment.

Keep your resolve to continue your quest of learning regardless of attractive alternatives there may be. Your future depends on it.

Ed Clingman, ISCET Administrator

FEEL THE POWER



# of ISCET Certification & Learning

THIS STUDY GUIDE IS DEDICATED TO THE SERIOUS STUDY OF ELECTRONICS THEORY!

You **WON'T** find any listings of Certification Administrators, Proctors or Members of Subject Matter Expert committees (SME) that together wrote this Study Guide. That is NOT to say that there is a problem with listing this information...but that we have allowed nothing to interfere with the serious nature of the material that is presented.

You **WILL** find material that is professional, written by ISCET, and edited by Mr. Joseph A. Risse, CET, one of the most eminent electronics writers of our time.

Any other information you might desire will gladly be furnished if available.

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STUDY GUIDE

for the

ASSOCIATE-LEVEL CET TEST

by

THE ISCET STAFF

Edited by Joseph A. Risse CET
5th Edition

Published by
THE INTERNATIONAL SOCIETY
of
CERTIFIED ELECTRONICS TECHNICIANS

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PREFACE TO FOURTH EDITION

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HOW TO USE THIS BOOK

This is a study guide. The guide provides guidance on what you should know in order to prepare for the Associate CET test. In order to fully prepare for the test, you should refer to other textbooks and other technical literature.

Some reference material you need might be available from ISCET headquarters. ISCET has a list of the books, articles, brochures, and other materials that are available. If you need additional information, contact ISCET (contact information is on the title page).

— Joseph A. Risse, CET

When you are ready to take the examination, contact ISCET to learn what material is currently available to establish the degree of knowledge you have obtained, and practice for the Associate CET examination.

When you are sure that you are ready, go to the ISCET website, www.iscet.org and click on the green button, "Register for an Examination," then follow instructions. If you have any questions or problems regarding exams, please contact the ISCET office at 800-946-0201.

The Associate Level CET Exam:
Any technician or student in electronics may take the associate level exam. The exam is the basic electronics portion of the full credit CET exam and must be passed with a score of 75% or better. The 75-question multiple choice test covers basic electronics, math, AC/DC circuits, transistors and basic troubleshooting.

The Journeyman Level CET Exam:
A fully certified technician must pass an entire CET exam, which consists of the Associate Level, plus one or more of several Journeyman options available in specific fields of electronics. These exams deal with more advanced theory which is applicable to audio, communications, computer, consumer, industrial, biomedical, radar and video electronics. A score of 75% or better is required for certification.

Test Sites:
Certification Administrators are located throughout the United States, Canada and many foreign countries. These persons are volunteers who have become administrators for the satisfaction of being able to contribute to the upgrade of the electronics profession. Contact the ISCET office for the name and address of those nearest to you.

Grading of Exams:
CET exams can be taken either by pencil and paper or by using the Online Testing System (OLT). When taken by pencil and paper, an electronic Scantron machine quickly and accurately grades each exam. When taken using the OLT the examinee is advised of his grade immediately. Using the Scantron requires the ISCET office to grade after transmittal to them of the cards used to record answers during testing. This normally requires 10 days to 2 weeks to report the test results back to the examinee. In both methods, Scantron and OLT detailed information is recorded and maintained to assess the viability of the exams being utilized.

The Test That You Will Take
Questions for the Associate-Level CET Test have been stored in a computer. To make a new version of the test, the computer selects the questions from the storage. all of the questions are multiple choice. mark your answer on a standard answer sheet. Figure 1-1 shows examples of the answer sheets used for the CET test. Tests may be taken either in pencil and paper or online by computer. Both types must be administered by an authorized ISCET Certification Administrator (CA) or Proctor.

If taken online, the answer sheet, as shown, will not be utilized. Regardless of the type of test taken, there is a "Formula Sheet" which has been developed giving you the major formulas for use. this is to aid you in the remembrance of the formulas ... and all electronic formulas are NOT shown, only those considered of major importance. You may use this "Formula Sheet" when taking the test. An example of this Formula Sheet is shown on the following page.

Caution!
NOTE THAT THE ANSWER SHEET IS NUMBERED HORIZONTALLY! IF YOU ARE A STUDENT, YOUR SCHOOL MAY BE USING ANSWER SHEETS THAT LOOK LIKE THE ISCET SCANTRON SHEET, BUT ARE NUMBERED IN A DIFFERENT WAY. BE SURE TO NOTE WHICH WAY YOUR ANSWER SHEET IS NUMBERED.

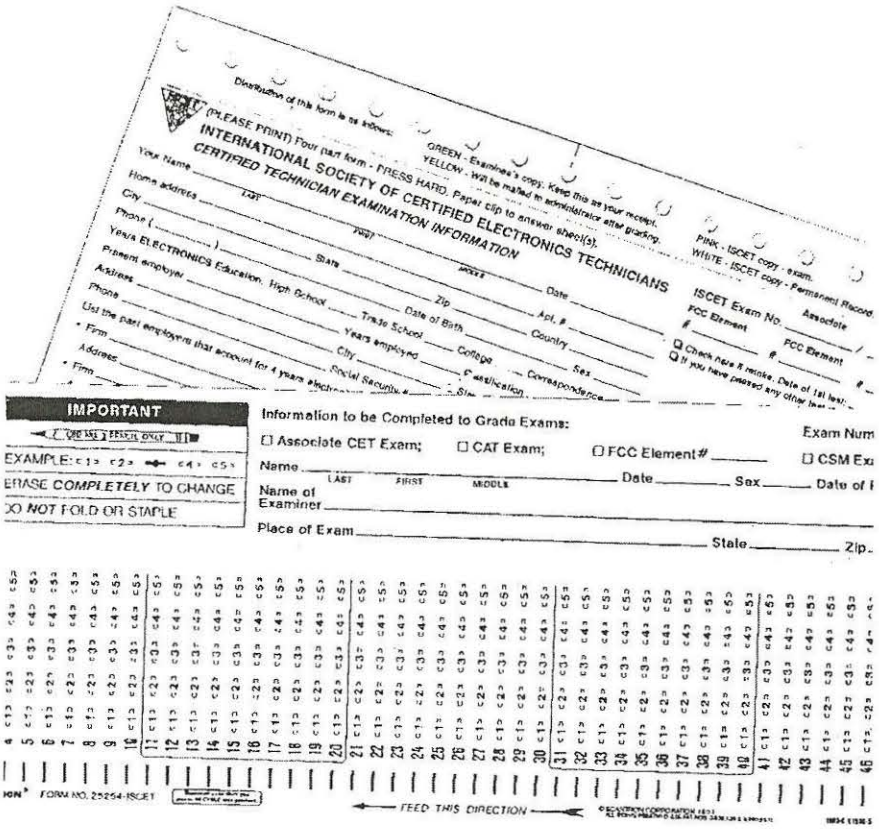


Figure 1-1

Figure 1-2

International Society of Certified Electronics Technicians

Associate Certified Electronics Technician

Expiration Date **Associate** **CET No.** AC

Be it Known by these Presents that

has successfully completed the Technical Tests and Continuing Education Requirements giving Universal Recognition for Competence, Ability and Knowledge as an Associate Certified Electronics Technician.

ISCET Chairman **ISCET Executive Director**

THIS SHEET MAY BE USED DURING TESTING

Formulas

Ohm's Laws

$$E = I R$$

$$P = I E$$

E = Voltage (Volts)
I = Current (Amps)
R = Resistance (Ohms)
P = Power (Watts)

RC Time Constants

$$t = R C$$

t = seconds
R = Ohms
C = Farads

RL Time Constants

$$t = \frac{L}{R}$$

t = seconds
R = Ohms
L = Henries

Capacitive Reactance (Ohms)

$$X_C = \frac{1}{2 \pi f C}$$

f = frequency in Hz.
C = capacitance in Farads

Inductive Reactance (Ohms)

$$X_L = 2 \pi f L$$

f = frequency in Hz.
L = inductance in Henries

Resonant frequency (Hz.)

$$f_r = \frac{1}{2 \pi \sqrt{L C}}$$

f_r = resonant frequency

Beta of a bi-polar transistor

$$\beta = \frac{I_C}{I_B}$$

Gain formulas for Class A amps

$$\text{Gain} = \frac{R_C}{R_E} \quad \text{or} \quad \frac{R_C}{Z_E}$$

As appropriate

The Associate-Level test is divided into the following sections:

Section I -Basic Mathematics - 5 questions

Section II -D-C Circuits - 5 questions

Section III -A-C Circuits - 5 questions

Section IV -Transistors and Semiconductors - 10 questions

Section V - Electronics Components and Circuits - 10 questions

Section VI - Instruments - 10 questions

Section VII - 15 Tests and Measurements - 15 questions

Section VIII - 15 Troubleshooting Questions

Each of these sections is discussed in this publication

A criticism that "this question belongs in that section." is sometimes made. Here is an example:

The D-C voltage across the emitter-resistor of a bipolar transistor is measured and found to be +20V. The emitter voltage is measured and it is slightly more positive than v. This means that ..... (five choices are given)

*This questions could be put in section II because transistors operate with D-C voltages.

*It could be put in Section IV because answering it correctly requires a knowledge of transistors.

*It could be put in Section V because the measurements are made in a transistor circuit.

*It could be put in Section VII because it is about a measurement.

*It could be put in Section VII because it is obviously a measurement made for evaluation the operation of the circuit. This is part of a typical troubleshooting procedure.

Not all of the questions in the test could be put into so many different categories. Some will obviously fit into only one category. However, the point is that the categories are not written in stone. They are guides to the way the test is made.
You should be able to answer the questions regardless of which section the question is given.
Figure 1-2 shows the Associate-Level certificate. Remember, to

become a Journeyman-Level CET you must take an additional test in your specialty.

Instructions for Taking the Test

It is very important for you to read the following instructions very carefully before taking the test:

--Do not write in the test book. Use the answer sheet to record your answers. You can use the back of the answer sheet for making calculations.

--There are no "trick" questions in this exam. Do not look for questions with two or more right answers or questions in which there are no correct answers.

-The purpose of the exam is to test your general knowledge of electronics and troubleshooting procedures. It does not require a specialized knowledge of the peculiarities of a particular brand-name system or test instrument. Therefore, answer the questions according to what is generally true -- not according to some special case that you may know of.

--If more than one answer appears to be correct, select the one this most correct without any qualifications. For example, consider this question:

Raincoats are:

(1) yellow

(2) waterproof

(3) plastic

(4) obsolete

To answer this question properly, choice (2) is most correct. It is true that raincoats may or may not be yellow,plastic, or obsolete. However, they are always supposed to be waterproof, so that is the correct answer of the choices.

You must correctly answer 75% (or more) of the questions to pass this exam. Educated guesses are appropriate. In other word, you are not penalized extra points for wrong answers. So, if you cannot decide between choices, pick the one you think is the best choice. Do not leave the answer blank because that will means you have no chance to get credit for that question.

--Read and answer each question carefully. Carelessness can cost you valuable grade points.

--There is a 2 hour time limit. Typically, it will take about one hour to complete your answer sheet.

--You may use a calculator provided it is NOT programmable in one or more alphanumeric readouts.

--No books or notes may be used.

--No talking during the test.

You can purchase a practice test from the ISCET office. That test will give you a chance to evaluate your training in various subjects before you take the actual test.

REMEMBER: if there is some subject area you don't understand in this study guide or in the practice test, you should do more study in that area. Obtain one or more appropriate reference books covering the required subject area. In other words don't depend complete on this study guide or the practice test. These are only guidelines to help point out where you need further study.

When you are ready to take the test, write to ISCET and ask for information. They will inform you about the cost of the test and name of the person in your area to call for a test appointment. The address of ISCET is inside the cover of this publication.

A Final Word

We don't say "good luck" when you take the CET test. It is not a matter of luck. Instead, it is a matter of knowing your subject area. This publication will help you over the areas that most technicians have trouble with on their first try.

COMPONENT REVIEW

There is no section in the Associate-Level test called **basic components.** However your knowledge of components will be very useful in answering many of the questions in different sections. For that reason, a brief review of resistors, capacitors, and inductor is given here.

Resistors

Figure 2-1 shows some of the resistor symbols that you will encounter in the test. Of the four symbols shown, Figure 2-1(a) is the one you see most often in schematic diagrams. It represents a resistor that has a linear resistance (within a certain range of current and temperature values). The term **linear** means that for example, if you double the voltage across it, the current through it will also double. Another way of saying this is that it follows Ohm's Law

In Figure 2-1 (b) is another symbol that is used for linear resistors. You will see this one in industrial diagrams, although it sometimes shows up in schematic diagrams. In any case, if you intend to take the Industrial CET Journeyman Test, be sure you are familiar with it.

The symbol shown in Figure 2-1 (c) is for a **varistor.** It is also known as a **glow bar** resistor. The term varistor comes from the words "voltage variable resistor". The resistance of this device **decreases** with an **increase** of voltage across it. Therefore it is not a linear resistor. You will see this component connected across the primary of transformers and inductors that are fed by semiconductor transistors. Its purpose is to prevent an inductive kickback voltage from destroying the transistor.

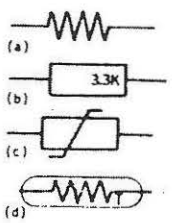


Figure 2-1

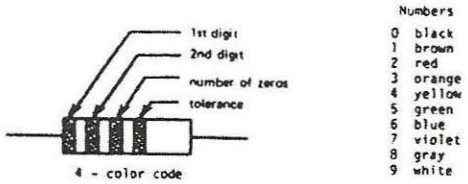


Figure 2-2

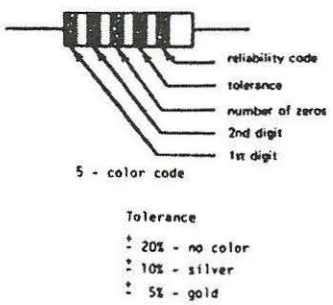


Figure 2-1

Figure 2-1 (d) shows the symbol for a **thermistor**. A thermistor is a temperature-dependent resistor and it is another example of a non-linear device The resistance of a thermistor depends upon its temperature. One example of its application is in sensing temperatures or temperature changes.

It is important to know that resistors are used for three purposes in circuits. If you keep these three purposes in mind, it will be easier to identify their operation in a circuit. The three purposes are to:

* Limit current

*Introduce a voltage drop

*Generate heat

The last one is the least often encountered. However, it is the principle of operation for the filament of the vacuum tube and the heater of a crystal oven, so it must be included with the uses.

By far, the most commonly encountered resistor is the carbon composition type, shown in Figure 2-2. These resistors have a resistance value that is determined by their color code. Be sure to note the five-color example shown in this illustration. The fifth color gives the failure rate. It is a reliability code that is not normally used by technicians. What it really tells is the number of resistors (in a certain family of resistors) that must pass a test in order for a manufacturer to accept all of the resistors in that family.

There are certain color codes that seem to be especially troublesome for technicians. In particular, these values are values between one and ten ohms, and values less than one ohm. For example a 4.7-ohm resistor has a three-color code of yellow, purple, gold. Figure 2-2 shows that the multiplier for gold is 0.1. This will always be the **third** band of the color-coded resistor.

In comparison, a 0.47-ohm resistor has a color code of yellow, purple, silver because silver is a 0.01 multiplier. Silver and gold are always multipliers when they appear as the third band.

Be sure you can read or write and identify color codes for resistances less than 10 ohms, using the color code.

There are two other color codes that seem to cause problems for technicians. These are color codes for multiples of 10 and multiples of 100. Keep in mind that the third band is normally used as a multiplier Therefore, for example the color code of a 10-ohm resistor is black, black, black. Black in the third band means
do not add any zeros. Technicians mistakenly tend to read this as 100 ohms because the colors are representing one, one, zero. Thus, the third color means to add zero zeroes. However the color code for 100 ohms is brown, black, brown. In this case,the third color representing 1 means to add one zero to the first two digits.

Some older resistors have a three-color code which is the same as the four-color code except there is no tolerance band. If there is no tolerance band, it means 20%, but that value of tolerance is no longer being manufactured. To replace one of those use a resistor of equal value that has a tolerance of 5% or 10%.

Questions on color code are sometime an integral part of some other questions. The following sample problem shows how knowing the color code is needed to answer an Ohm's Law problem:

SAMPLE CET TEST QUESTION

Which of the following color codes is correct for the resistor in Figure 2-3?

(1) brown, black, red
(2) brown, black, orange
(3) brown, black, yellow
(4) brown, brown, red

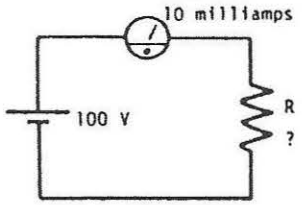


Figure 2-3

ANSWER: By Ohm's Law, (R = V/I) the resistance is calculated to be 10,000 ohms. The correct color code for a 10k resistor is given in selection (2).

You must be familiar with all the facets of Ohm's Law Be sure you know how to calculate power dissipation for resistors in simple DC and AC circuits. Here is another sample problem:

SAMPLE CET TEST QUESTIONS

The power dissipated by the resistor in Figure 2-4 is

(1) 40 watts

(2) 4 watts

(3) 8 watts

(4) 0.8 watts

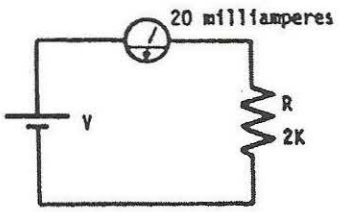


Figure 2-4

ANSWER: Choice 4 is correct. The power is equal to square of the current multiplied by the resistance.

What is the battery voltage in the circuit of Figure 2-4?

(!) 40 V (3) 100 V

(2) 400 V (4) 10 V

ANSWER; Choice (1) is correct. By Ohm's Law, the voltage equals the current times the resistance or,

V = IR
= 0.02 A x 2000 ohms
= 40 volts

Remember that carbon resistors are very noisy compared with film types. You can substitute a film resistor for an equal value of carbon resistor. However, be careful about substituting a carbon resistor for a film resistor.

Also, do not substitute a wire-wound resistor for either type because wire wound resistors have inductance which could affect the performance of your circuit. Additionally, in some circuits, the inductive characteristics of carbon and film resistors have to be considered. When replacing a resistor in a high frequency or critical circuit be careful of the inductive characteristics of the replacement.

In your test, you may also expect questions on variable resistors. One important thing to know is how to determine if a variable resistor is connected as a rheostat or a potentiometer.

Figure 2-5 shows the difference between the two connections. As shown in Figure 2-5 (a), a rheostat is a two-terminal device. It is connected so that it controls the **current** to the load. A potentiometer, shown in Figure 2-5 (b) is connected so that it controls the **voltage** to the load. A potentiometer is a three-terminal device.

Sometimes potentiometers have linear or nonlinear ratings. A linear potentiometer will have the same amount of resistance for a given number of degrees of rotation. A nonlinear volume control,

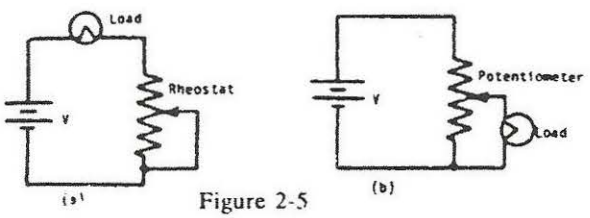


Figure 2-5

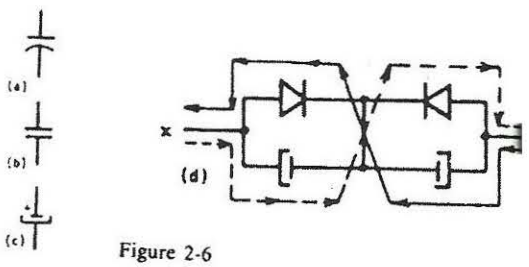


Figure 2-6

Figure 2-5 Figure 2-6

or one with an audio taper, is a volume control that has more or less resistance for a given number of degrees of rotation of the

shaft. This is to accommodate the difference in response of the ear to changes in audio volume.

Capacitors

Figure 2-6 shows some of the capacitor symbols that you will encounter in a CET test. Be sure to check reference books for their types and shapes such as ceramic, tantalum, polyesters, etc.

The symbol shown in Figure 2-6 (a) is the one used most often in schematic diagrams. The one shown in Figure 2-6 (b) is out-of-date. One reason it is out of date is because the symbol in (b) is often used in electrical or industrial diagrams to indicate the contacts of a relay or switch. If you used this for both switch and capacitor diagrams you wouldn't be able to tell which was which. So the symbol shown in Figure 2-6 (b) should not be used. However is still appears in some older diagrams and foreign made electronic equipment.

The symbol for an **electrolytic** capacitor is shown in Figure 2-6 (c) As shown by the positive sign, this type of capacitor is **polarized. This type of capacitor must not be connected in series in a high-voltage AC circuit because a reverse voltage across the capacitor can destroy it.**

The reason for using electrolytic capacitors in the first place is that you can get a large amount of capacitance in a very small package.

Some books show ways, such as in Figure 2-6 (d), of connecting electrolytic capacitors back-to-back or in reverse, but this is not recommended here.

If a capacitor is being used in a circuit, it is assumed that there is a charge and a discharge path for it. You may be asked on the test to identify the charge or discharge path of a capacitor in a circuit such as a relaxation oscillator.

SAMPLE CET TEST QUESTION

The discharge path for C, in the circuit of Figure 2-7, is shown by the arrow marked

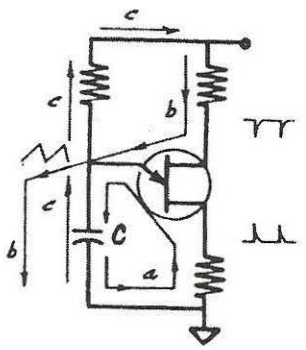
(1) a

(2) b

(3) c

(4) none of these answers is correct

Figure 2-7



ANSWER: (1) 'a' is correct -- the **charge** path is shown by the arrow marked 'c'.

As with resistors, there are three main uses of capacitors.

Keep this in mind and it's easier to identify their use in a circuit. Capacitors are used for

* storing energy
* introducing time delay (as in time-constant circuits)
* introducing a voltage drop

It can be argued that there is really only one application -- this is, storing energy. However, the three uses are given here in order to distinguish them in various circuits.

Inductors

You will not be required to calculate the inductance of an inductor in a CET test, but you should know what factors determine that inductance. Those factors are: **the permeability of the core material; the number of turns;** and **the shape factor.**

Permeability is a measure of how easy it is to store a magnetic material in an inductor.

The **number of turns** of an inductor directly determines its inductance. In other words, the greater the number of turns, the greater the inductance value.

The **shape factor** is defined by the relationship between the length of the coil and the radius of the coil. This shape factor is often given as a relationship between the area across the core and the length of the coil.

For a coil having a given length of turns, the inductance will **decrease** if the coil length is increased. (You can remember this because if the length is increased to the point where the coil becomes a straight wire, its inductance is minimum).

Remember, coils are used to store energy in the form of an electromagnetic field. They can also be used to produce an AC voltage drop (as in the case of filter circuits), and to introduce time delay in circuits where they are connected with resistors.

SAMPLE CET TEST QUESTION

What is the time-constant of a circuit that has a 250-millihenry coil connected in series with a 250-ohm resistor?

(1) one microsecond

(2) 62.5 milliseconds

(3) 62.5 seconds

(4) one millisecond

ANSWER; (4)

The time-constant equation for L-R circuits is T= L/R where L is in henries and R is in ohms

In this particular case T = L/R = .250/250 sec = 1 millisecond

You can expect to have some questions on transformers, but the transformers may be connected as an integral part of a circuit. An important feature of a transformer is the dot notation indicated in Figure 2-8. **The dot notation indicates two points in the transformer where the voltages are in phase.**

Before you take the test, review the relationship between the turns ratio of the transformer and the voltages, currents, or impedances. However questions may be designed to test your knowledge of those relationships. Here is an example:

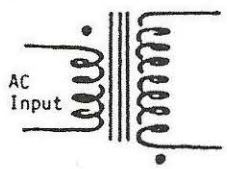
SAMPLE CET TEST QUESTION

For the transformer shown in Figure 2-9, the higher secondary voltage will occur when the switch is in the position marked

Figure 2-8

(1) X

(2) Y



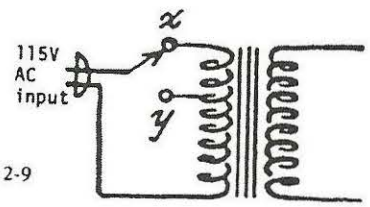


Figure 2-9

ANSWER (2)

A transformer turns ratio is the ratio of the number of turns in the primary winding to the number of turns in the secondary.

SAMPLE CET TEST QUESTION

A certain transformer has a turns ratio of 1:25. If its secondary voltage is 5000 V, its primary voltage is

(1) 200 V

(2) 125,000 V

ANSWER (1) Voltages are in direct proportion to turns ratio, but currents are in reverse proportion.

$$\frac{N_1}{N_2}=\frac{V_1}{V_2}=\frac{1}{25}=\frac{V_1}{5000}=\frac{I_2}{I_1}=\sqrt{\frac{Z_2}{Z_1}}$$

SURFACE MOUNT COMPONENTS

Surface mount technology is a relatively recent development in the field of electronics. Surface mount technology or SMT is a manufacturing technology in which electronic components without leads are soldered to contacts on the surface of a circuit board or panel. The components are leadless. That is, they are soldered directly to a mating board that does not have holes for insertion. The soldering is directly from the flat tab or stub of the component to the surface of the flat board. Surface- mount components include resistors, capacitors, inductors, diodes, trimmers, and low-profile transistors and integrated circuits.

Surface-mount components or surface-mount devices (SMDs) have become widely used in electronics devices of all kinds including, TVs, radios, VCRs, CDs (compact discs), computers and industrial equipment. While SMT has become increasingly popular many components are still being fastened to circuit boards by passing leads of components through holes in circuit boards and soldering them. This method is known as insertion or insertion-mount technology.

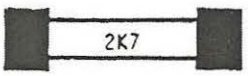
SMT has a number of advantages. For one, the opposite side of the board is left free for mounting other components, allowing reduction of equipment size. Also, smaller-size components are possible. And more efficiency is possible in the manufacture of components.

SMDs are seldom color coded. A method of coding SMDs that has been used in the past is shown In Figure 2-10. In this system, the color is usually light colored and the ends are flat C-

RESISTORS

FIGURE 2-10

Figure 2-11



shaped, metallic conductors that clamp onto the component
and are soldered to the foil surface of the board. As mentioned before, SMDs are rarely color-coded. In Figure 2-10, the number 223 is stamped onto the body of the resistor. The number 22 represents the significant digits and the 3 is the multiplier representing 1000 or the number of zeros. Thus, 223 means 22,000 ohms. A resistor labelled 561 would have a value of 560 ohms, and one labelled 465 would have a value of 4.600,000 ohms or 4.6 Megohms

Another system used at one time is shown in Figure 2-11 where, in the value 2K7, the letter K is used both as a decimal point and a multiplier. Thus 2K7 is read as 2.7K or 2700 ohms. For other values of resistors other letters are used. For example a resistor labelled 6M8 has a value of 6.8 megohms, and 2R7 has a value of 2.7 ohms, 33R means 33 and no zeros, 1R0 means 1.0 and no zeros, 4R0 means 4.0 and no zeros, and so on.

At the present time, surface-mount components are made even smaller and without the C-shaped ends, as is shown in Figure 2-12. The coding is the same, such as 202 for 20 and two zeros in Fig 2-12 or 33R for 33 and no zeros as in Figure 2-13, or R33 for 0.33 ohms, and so on

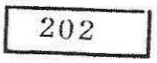


Figure 2-12

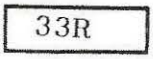


Figure 2-13

The nominal resistance in ohms is identified by the three digits for 2% and greater tolerance. The first two digits represent the significant figures and the last digits is the decimal multiplier or the number of exponents that must be added to the significant figures. For values less than 100 ohms, the letter R is substituted for one of the significant digits and represents a decimal point. Table 2-1 lists some more examples of resistor codes and their values.

Table 2-1
Examples of Resistor Codes and Their Values

Numerical Code	Value
221	22 and 1 zero, or 220 ohms
333	33 and 3 zeros, or 33,000 ohms
2R0	2 and no zeros, or 2 ohms
11R	11 and no zeros, or 11 ohms
R30	0.3 and no zeros, or 0.1 Ohm

Figure 2-14

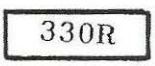


Figure 2-15

Where the tolerance is less than 2%, a four-digit code is used where the first three digits represent the significant figures and the last digit represents the multiplier. For example, in Figure

2-14, 2001 represents 2000 ohms; 330R indicates a 330-ohm resistor, as in Figure 2-15, and 22R0 represents a 22-ohm unit

Capacitor and Inductor Codes

Capacitors also are often coded with markings and numbers to identify their values, temperature ratings, and tolerances. Inductors are identified by different colors of dabs of paint; and diodes usually are marked with a part number and a means of identifying the cathode end of the diode. Most transistors are clearly marked with the part number, as are integrated circuits.

A method used for capacitors and sometime for resistors is the letter/number system. A single letter indicates the significant value and a single number is the multiplier. The values are shown in Table 2-2. The basic unit is pF or picofarads:

Table 2-1
Capacitor, Significant Figures Code

A =1 B=1.1 C=1.2 D=1.3 E=1.5 F=1.6 G=1.8
H=2.0 J=2.2 K=2.4 L=2.7 M=3.0 N=3.3 P=3.6
Q=3.9 R=4.3 S=4.7 T=5.1 U=5.6 V=6.2 W=6.8
X=7.5 Y=8.2 Z=9.1 a+2.5 b=3.5 d+4.0 f=5.0
m=6.0 n=7.0 t=8.0 y=9.0

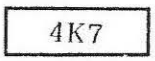


Figure 2-16

SAMPLE CET TEST QUESTIONS

What is the value of the resistor on a SMD board as shown In Figure 2-16?

(1) 4.7 ohms
(2) 4700 ohms

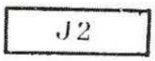


Figure 2-17

ANSWER (2) is correct. The example in Figure 2-16 shows the resistor is labelled 4K7. The K is used as a decimal point. and also indicated kilo, or as a multiplier of 1000. Therefore the value represented by 4K7 is 4.7K or 4700 ohms.

What is the value of the capacitor shown in Figure 2-17?

(1) 220 pF
(2) 2200 pF

ANSWER (1) is correct. The capacitor is marked J2. From the significant figures table the code J has the value 2.2 and the 2 means multiply by 100. The value therefore is 2.2 x 100 = 220 pF.

BASIC MATHEMATICS

The first section in the CET test is entitled "Basic Mathematics." Occasionally you will hear a technician say that he studied mathematics but he never had an opportunity to use it. This would be almost impossible for a technician who is working in electronics.

There are two reasons for studying mathematics. One purpose is to enable you to determine the amount of voltage or current (or other value) at some particular point in a circuit so that you can determine if your test results are accurate.

There is another important reason for studying mathematics. The mathematics tells you the relationship between the parameters and the circuit. If it weren't for the math equations, you would have to learn complex sentences just to describe the relationship between voltage, current, and resistance in a simple DC circuit like the one shown previously in Figure 2-4.

SAMPLE CET TEST QUESTION

The resistance in the circuit of Figure 2-4 is too high. This means that the current is

(1) too low

(2) too high.

ANSWER; (1) You know this without having to work the problem because you know Ohm's Law (I=V/R). You know that an increase in R will cause a decrease in I. Working a lot of Ohm's Law problems gives you the insight needed to answer this type of question.

Be sure that you have a clear understanding of the mathematical relationships in simple A-C circuits. A common error is to try to add the voltages across the components in an A-C circuit to obtain the value of the generator voltage. This type of error comes from an misunderstanding of Kirchoff's Voltage Law which says: The algebraic sum of the voltage around any closed loop is zero. **That law applied directly to D-C circuits only.** If you want to apply the law to A-C circuits, you have to modify the law to say the **vector sum** (or phasor sum) of the voltages around any closed loop must be equal to the vector of the applied voltage. The word phasor is usually used instead of vector in reference to electrical and electronic circuitry. Figure 3-1 shows a simple circuit of the type you may encounter in a test.

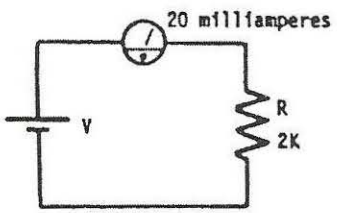


Figure 2-4

(Repeat from page 2-2)

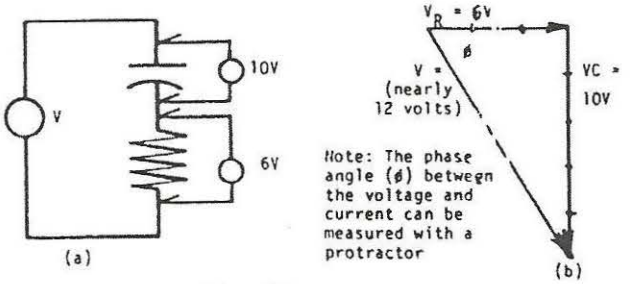


Figure 3-1

SAMPLE CET TEST QUESTION

Refer to Figure 3-1 (a). The applied voltage (V) in this circuit must be

(1) 4.13 volts

(2) 8.31 volts

(3) 11.66 volts

(4) 16 volts

ANSWER; (3) The voltages add as vectors like the reactance and resistances. Figure 3-1 (b) shows the graphic solution. Note that V_R and V_C are combined at right angles and the hypotenuse is the resultant (V). The answer is approximately 12 volts. (Remember, This is a **graphical** solution.) A mathematical solution can also be obtained.

You may be asked to calculate the value of resistances in series and in parallel as shown in Figure 3-2. The equations are given for the solution. Likewise, you may be asked to calculate the capacitance of a series or parallel combination as shown

$$V=\sqrt{V_x^2 + V_c^2}$$

$$=\sqrt{6^2 + 10^2}$$

$$=\sqrt{136}$$

$$=11.66V$$

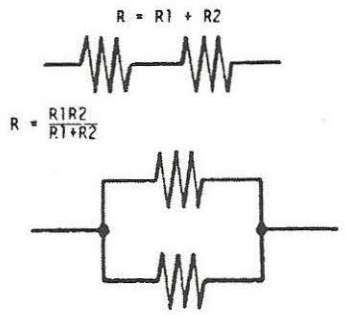


Figure 3-2

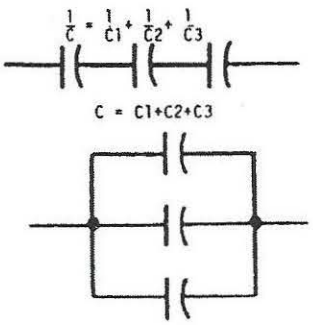


Figure 3-3

in Figure 3-3. Be sure your can make these simple calculations before you take the CET test. You will NOT be asked to make computations regarding series and parallel inductance because those values are complicated by coefficients of coupling and mutual inductance. Besides, they rarely occur in practical circuits.

Binary and Decimal Mathematics

Your Associate CET test will likely include some questions on converting between decimal and binary numbers. Knowledge of these number systems is now required by technicians working in industry as well as on consumer electronics equipment.

Some discussion is included in this section on both these number systems for the purpose of emphasizing their growing importance. Aside from what we cover here, howover, you should review further using other books on number systems.

BINARY NUMBERS

To answer many of the questions in the Associate CET Test, a knowledge of basic mathematics is needed. Most of the questions requiring an ability with math are based on our everyday decimal number system. That system uses the digits 0, 1, 2, 3, and so on, through 9. It is assumed that you have the ability to do math using decimal numbers. If you're a little rusty, you should brush up before taking the test.

Another number system, the **binary** number system, may also be the basis for other questions in Associate and Journeyman CET tests. An introduction to the binary system follows. But you might wish to refer to additional sources on binary number math to feel fully confident to handle those types of problems.

Binary Number System

While, in the decimal system, the basis or radix is 10 (there are ten digits 0 through 9) in the binary system the base is 2. The binary system uses only two different digits, 0 and 1, in various combination. to represent numbers of different values. In some cases, two other characters, such as yes and no, high and low, on and off, can also be used, but most often we use 0 and 1.

The value of a digit in the binary system depends on which digit it is -- 0 or 1 -- and on its relative position, just as in the binary system. But if a binary digit is 0, its value is zero in any position.

Positional value in binary is a function of the power of 2. Therefore, a digit at the extreme right in a whole binary number is a function of the 0 power of 2, or 2^0, or 1. (Remember, any number to the 0 power is 1). Then, the next digit to the left is a function of the first power of 2, or 2^1, or 2. Similarly, the next digit to the left is a function of the second power of 2 or 2^2, or 4; the next function of the third power of, or^3, or 8, and so on. In the simplest case, the binary digit 0 has a value of 0, and the binary digit 1 has a value of 1.

Analyzing a multiple-digit binary number can be simplified by referring the Table 3-1. This table relates to whole binary numbers which may be imagined to have a binary point at the right of the whole number, just as there is an imagined decimal point to the right of a whole decimal number. (There are also binary numbers having digits following the binary point, but we will not discuss those here.)

TABLE 3-1 Position Values for Binary Digits as Powers of 2 and Decimal Equivalents

	Positions to Left of Binary Digit							
Position	8th	7th	6th	5th	4th	3rd	2nd	1st
Power of 2	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal Value	128	64	32	16	8	4	2	1

For the binary number 11010, from Table 3-1, we write down the positional values, and write the sum of the values for the positions where 1's appear Wherever there is a zero, the value for that position is 0.

Therefore, starting at the extreme right digit of the binary number 11010, and proceeding to the left, thus the binary number 11010 is equivalent to the decimal number 26.

Binary										Decimal
0	=	0	x	2^0	=	0	x	1	=	0
1	=	1	x	2^1	=	1	x	2	=	2
0	=	0	x	2^2	=	0	x	4	=	0
1	=	1	x	2^3	=	1	x	8	=	8
1	=	1	x	2^4	=	1	x	16	=	16
										Total 26

Simplifying Binary Operations

In many cases, it isn't necessary to go through the powers of 2 routine to come up with the value of a binary number. Usually you can do it mentally. All you need do is learn the positional values, which is fairly simple. Just keep in mind that the digit at the extreme right has a positional value of 1, the next digit has a positional value of 2, the next 4, the next 8, the next 16, and so on. Each digit has a positional value twice that of the preceding one. Just look at the binary number and add up all the positional values where 1's appear. The simplest example is a binary number having all 1's, such as 11111. Starting at the extreme right, the value of this digit is 1, the next to the left has a value of 2, the next has a value of 4, the next has a value of 8,, the next has a value of 16. Summing these up in your mind, you say to yourself, 1 plus 2 plus 4 plus 8 plus 16 is equal to the total of 31.

Now, taking an example with a zero such as 10111, starting at the extreme right,

1 plus 2 plus 4 plus 0 plus 16 = 23

Binary numbers can be of any length, that is, they can have any number of digits.

Binary Coded Decimal Numbers

A multiple-digit decimal number of any size can be represented in binary form. However, in some cases, the number of binary digits needed can become cumbersome. For example, decimal 238 in binary form is 1101110. In many cases, in electronic circuits and equipment, binary numbers are converted to BCD, or Binary Coded Decimal form. To convert a binary number to BCD form the conversion is done by listing a four bit number for each decimal digit. For example, decimal 429 converted to BCD is

0100 0010 1001

The BCD group 0100 is equivalent to decimal 4, the group 0010 is equivalent to decimal 2, and the group 1001 is equivalent to decimal 9. There are always 4 digits in a BCD group, and the highest any group can total is 9. Binary equivalents for decimal 0 through 9 are shown in Table 3-2.

TABLE 3-2

Binary-Coded Decimals (BCD Numbers)

Binary	Decimal
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9

EXAMPLES

The following examples will provide you with some practice in converting binary numbers to decimal numbers and in converting decimal numbers to BCD.

EXAMPLE 1; Convert the binary number 101010 to its decimal equivalent.

SOLUTION; You can do this mentally as follows, starting at the rightmost digit:

0 plus 2 plus 0 plus 8 plus 0 plus 32 = 42

or, you could do it the longer way. First list the binary number vertically, starting the rightmost digit, then write in the positional values

0	=	0	x	2^0	=	0	x	1	=	0
1	=	1	x	2^1	=	1	x	2	=	2
0	=	0	x	2^2	=	0	x	4	=	0
1	=	1	x	2^3	=	1	x	8	=	8
0	=	0	x	2^4	=	0	x	16	=	0
1	=	1	x	2^5	=	1	x	32	=	32
										Total 42

EXAMPLE 2; Convert the decimal number 4637 to BCD form.

SOLUTION; This is done bit by bit, as follows: Decimal 4 is equivalent to binary 0100, decimal six is binary 0110, decimal 7 is equivalent to binary 0111, and decimal 3 is binary 0011. Thus, the BCD equivalent of 4673 is

0100 0110 0111 0011

Division Method of Converting from Decimal to Binary

You've seen how to convert binary to decimal. It is sometimes also necessary to convert from decimal to binary, and you might run into a question of this type on the Associate or Journeyman tests. There are two method of converting from decimal to binary. One of these is the **progressive subtraction method.** The other is the **modulo division method.** For the progressive subtraction+ method, Table 3-3 will be useful, along with the following steps,

TABLE 3-3

Powers of 2

Exponent of 2	Decimal Value	Binary Position
0	1	1
1	2	10
2	4	100
3	8	1000
4	16	1 0000
5	32	10 0000
6	64	100 0000
7	128	1000 0000
8	256	1 0000 0000
9	512	10 0000 0000
10	1 024	100 0000 0000
11	2 048	1000 0000 0000
12	4 096	1 0000 0000 0000
13	8 192	10 0000 0000 0000
14	16 384	100 0000 0000 0000
15	32 768	1000 0000 0000 0000

A. Locate the largest power of 2 value that can be subtracted from the decimal value to be converted. That power of 2 represents the position of the most-significant bit (the leftmost bit)in the binary value that will result. Enter a 1 in that position.

B. Subtract that largest power of 2 from the decimal value to be converted. The difference now becomes the next value from which a power of 2 must be subtracted.

C. Repeat steps A and B until the decimal value is reduced to zero.

D. place a 0 in all bit positions where a 1 has not been entered during steps A through C. Do not omit a trailing zero

EXAMPLE;

Convert decimal number 3274 to binary.

SOLUTION; The 11th power of 2, decimal 2048, is the highest power that can be taken from 3274 so a 1 goes at bit 11. (Refer to Figure 3-4). Next, subtract decimal 2048 from 3274. This leaves 1226.

The 10th power of 2 can be subtracted from that so another 1 goes at bit 10. Continue the subtraction: the 9th and 8th powers of 2 are too large for 202, but the 7th power, 128 can be subtracted from 202 leaving of difference of 74. The 6th power, 64, may be subtracted from 74, with a difference of 10. The 3rd power, 8, subtracted from 10 leaves 2. Last, the 1st power of 2 can be taken from 2. The result of the overall operation is that there should be a binary 1 at bits 11, 10, 7, 6, 3, and 1; and there should be 0's at bits 9, 8, 5, 4, and 2. Thus decimal 3274 has been converted to binary 110011001010.

DECIMAL TO BE CONVERTED:		3274
		3274
LARGEST POWER OF 2	(2^{11})	−2048
		1226
LARGEST POWER OF 2	(2^{10})	−1024
		202
	(2^{7})	−128
		74
	(2^{6})	−64
		10
	(2^{3})	−8
		2
	(2^{1})	−2
		0

BINARY PATTERN FORMED (BITS)

11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	0	1	1	0	0	1	0	1	0

Figure 3-4 Converting decimal 3274 to binary using progressive subtraction method.

Modulo Division Method of Decimal to Binary Conversion

In the modulo division method of converting a decimal number to binary, you divide successively by the base 2, saving only the remainders. The example, explained next, and illustrated in Figure 3-5, shows how to convert decimal 1468 to base 2 binary

```
1468 / 2     R = 0  LEAST SIGNIFICANT BIT
 734 / 2     R = 0
 367 / 2     R = 1
 183 / 2     R = 1
  91 / 2     R = 1
  45 / 2     R = 1
  22 / 2     R = 0
  11 / 2     R = 1
   5 / 2     R = 1
   2 / 2     R = 0
   1 / 2     R = 1  MOST SIGNIFICANT BIT
RESULT:    10110111100
```

Figure 3-5. Converting decimal 1468 to binary, using modulo method.

The method is based on the following steps.

A. Divide the decimal value by 2.
B. Write down the remainder, either 1 or 0. The remainder is the least significant bit of the final binary value.
C. Divide the quotient thus derived by 2 again
D. Once more, write down the remainder. This is the next bit of the binary value.
E. Repeat steps C and D until the quotient is zero.

In Figure 3-5 the quotient for 1468 divided by 2 is 734. Enter the remainder, which is zero. This zero is the least significant bit (the zero bit) of the final binary number. The quotient 734 divided by 2 is 367 with a remainder of 1. This one is the next most significant bit. Repeat steps C and D until there are no remaining quotients. Note that a decimal value which ends in an even digit leaves a zero remainder of 1. The final step must always take that form, with the result always being 1. Thus, the most significant bit will be 1 since leading zeros have no value or meaning.

Pulses Representing Binary Numbers

Binary numbers may be represented electronically by the use of pulse patterns. Arrangements of pulses that are present and that might be considered absent or missing can be represented by the pulse pattern shown in Figure 3-6. Alongside each pulse series are its equivalent binary and decimal numbers. that is, pulses 1, 2, and 3 are absent, and pulse 4 is present, that pulse series represents binary 0001 or decimal 1. Another example representing

decimal 6 or binary 0110 is represented by the pulse series where pulses 2 and 3 are present and pulses 1 and 4 are absent.

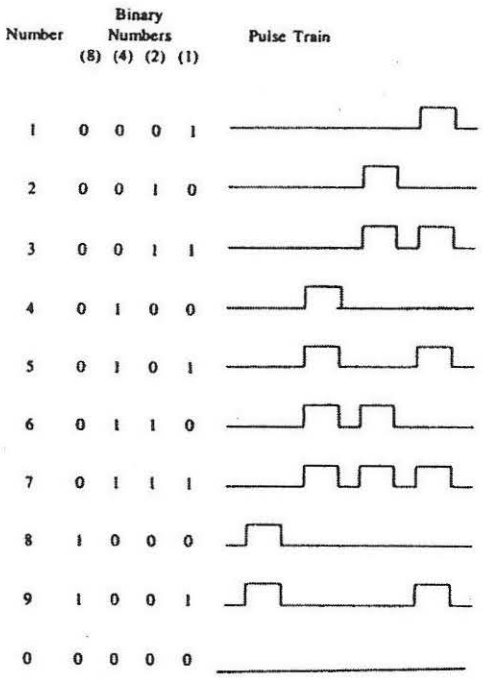


Figure 3-6. Pulse representation of decimal and binary numbers.

EXAMPLE; What decimal number is represented by a pulse series where pulses 1 and 3 are absent, and pulses 2 and 4 are present?

SOLUTION; This is equivalent to decimal 5, or binary 0101, as shown in Figure 3-6.

HEXAECIMAL NUMBERS

Hexadecimal Numbering System

Because of the simplicity and regularity of the binary system, binary numbers are the natural language of binary and microprocessor circuits. Binary numbers that represent large decimal numbers, however, get to be quite lengthy. That is, they require long strings of binary digits which are cumbersome for the technician to handle. For that reason, technicians sometimes

represent binary numbers with other number systems which require fewer digits. One of these other number systems which the electronics technician and engineer should have at least an introductory knowledge of is the **hexadecimal numbering system.** Sometimes this is called the "hex" system for simplicity. The hexadecimal system is a base 16 system. It uses 16 characters rather then 10 as in the decimal system, or rather than 2 as in the binary system.

You might encounter a test question requiring conversion from hex to decimal, or hex to binary, or either of these in reverse order. Therefore a brief discussion is provided here of the hexadecimal number system.

Any group of four binary digits can be represented by a single character or symbol in the hexadecimal system. The hexadecimal numbers are 0 through 9 plus the letters A through F. The increasing oder of magnitude is 0, 1, 2, 3, 4, 5, 6. 7. 8. 9. A, B, C, D, E, F. Hexadecimal numbers and their binary and decimal equivalents are compared in Table 3-4.

Table 3-4
Binary, Hexadecimal, and Decimal Equivalents

Binary	Hexadecimal	Decimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

Converting From Binary to Hexadecimal

The first step is to learn how to convert any binary number to its hexadecimal equivalent. To start, just divide the binary number into groups of four binary digits, starting at the rightmost digit. If the end leftmost group does not have four digits, add enough zeros to the left of that group to make it a four-digit group Next, replace each binary group with its hexadecimal equivalent.

EXAMPLE; Convert the binary number 1110001101010 to its hexadecimal equivalent.

SOLUTION; Starting at the right of the binary number and dividing it into four-digit groups, we get

0001 1100 0110 1010

Note that it was necessary to place three zeros in front of the leftmost digit in order to create a four-digit group. Next, we place the hexadecimal equivalent under each group, using Table 3-4

0001 1100 0110 1010

1 C 6 A $= 1C6A_{16}$

The subscript 16 indicates that this is a hexadecimal number.

Another example, to convert the binary number 111100111001111, first separate it into four groups, add zeros if needed, and convert it to hex,

0011 1100 1100 1111

3 C C F $= 3CCF_{16}$

In a reverse manner, a hexadecimal number can be converted to a binary number by listing the binary number, and then placing the binary groups under each hexadecimal character.

EXAMPLE; Convert the hexadecimal number FC3A to binary.

SOLUTION; From Table 3-4, place the equivalent binary group under each hexadecimal character.

F C 3 A

1111 1100 0011 1010

Thus hexadecimal FC3A is equivalent to binary 1111110000111010

This review of hexadecimal numbers is sufficient at this point to prepare you for any questions on hex in the CET test. There are other methods of converting, such as by the division method and the expansion method and a method by use of a table. It could be worth your while to review these from a reference book covering hexadecimal numbering systems.

D - C CIRCUITS

One of the most important things that you must know how to do is to calculate voltages, currents, and resistances in D-C circuits. A technique called the **proportional method** greatly simplifies some of the problems you might encounter in a CET test. The proportional method is illustrated in Figure 4-1. The problem here is to find the voltage across each series resistor when the applied voltage (V) is known, One way to approach this problem is the calculate the current in the circuit then, by Ohm's Law, find the voltage across each resistor. However, if you use the two equations shown in Figure 4-1, it's easy to determine the voltage across each resistor without finding the current first.

For example, for V1, the proportional method is

$$V_1 = V \frac{R_1}{R_1 + R_2}$$

and, for V2

$$V_2 = V \frac{R_2}{R_1 + R_2}$$

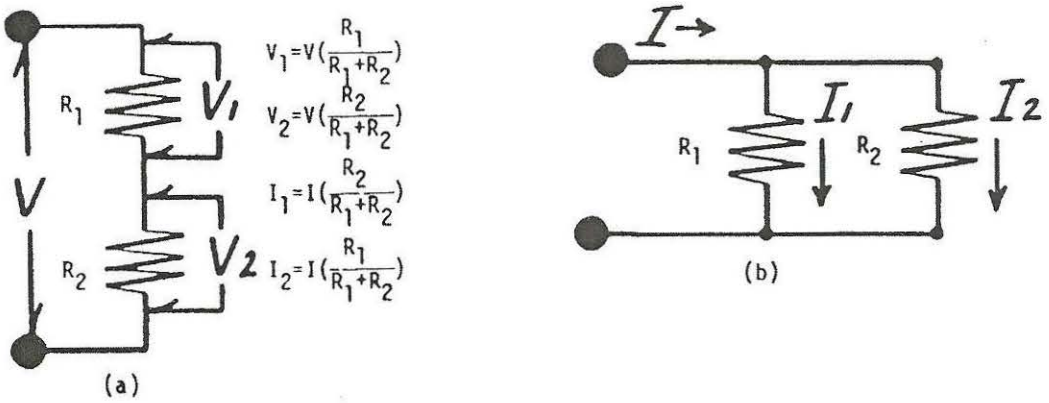


Figure 4-1.

The proportional method for finding current in parallel resistors is also shown in Figure 4-1. The current entering each branch is known, and the problem is to determine the current through each resistor. This could be done by finding the parallel resistance, then by determining the voltage across that parallel combination That would give you the voltage across R1 and R1, and from that you could find the currents.

A simpler way to find the currents directly by using equations for I1 and I2 is shown in the illustration. Be sure to note that the resistance in the numerator in these equations is always opposite of the way in which the resistance is being found. So, when you're finding the current through R1 (which is I1) you use the ratio of R2 divided by the sum of R1 + R2).

On the test, a large number of technicians miss the simple problem illustrated by Figure 4-2. This is a simple voltage divider. The only difference between it and the other voltage dividers is that it is connected between and positive and a negative source . The voltages are always given with respect to ground.

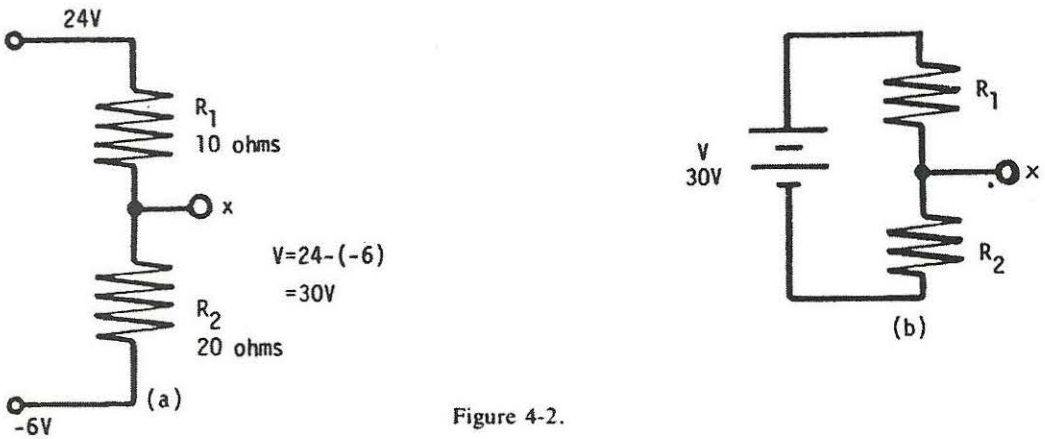


Figure 4-2.

SIMPLE CET TEST QUESTION;

For the circuit in Figure 4-2 (a), find the voltage at test point (x) with respect to the common point. The value of voltage is:

(1) 6V

(2) 14V

(3) 15V

(4) 16V

ANSWER; (2) The circuit is redrawn in Figure 4-2 (b) to shown the equivalent voltage source of 30V. **First** find the voltage across R1 by the proportional method,

$$V_1 = V \frac{R_1}{R_1 + R_2}$$

$$= 30 \frac{30}{10 + 20}$$

$$= 30 \times \frac{1}{3}$$

V = 10 VOLTS

Second, subtract the voltage across R1 from the applied voltage in Figure 4-2 (a).

$$V_x = V_{24} - V_1$$

$$= 24 - 10$$

$$= 14 \text{ volts (answer)}$$

Figure 4-3 shows another kind of problem that you will see in the D-C circuit section. In this case a voltage source V and its internal resistance Ri are connected across a variable resistor R_L The question that usually is given with this circuit is: What value must R_L be adjusted to in order that it will receive the maximum possible power from the power source. You may also be asked what is that value of power delivered to R_L when maximum power is being delivered? These values will be determined in the following sample problem.

SAMPLE CET TEST QUESTION

In the circuit of Figure 4-3. what value of R_L will receive maximum power from the battery and its internal resistance (Ri)?

(1) 60 ohms

(2) 84 ohms

(3) 120 ohms

(4) infinity

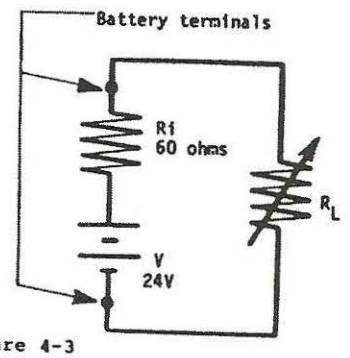


Figure 4-3

Figure 4-3

ANSWER; According to the **MAXIMUM POWER TRANSFER THEOREM FOR D=C CIRCUITS,** the maximum power will be delivered to the load resistor when its resistance equals the internal resistance of the source.
The answer is (1).

SAMPLE CET TEST QUESTION

What is the value of the maximum power delivered to R_L in the circuit of Figure 4-3?

ANSWER; For maximum power R_L must be adjusted to 60 ohms. That is the value of internal resistance. The resultant circuit is shown in Figure 4-4. By the proportional method, the voltage across the load resistor V_L is:

$$V_L = V/2$$

$$= 24/2$$

$$= 12 \text{ V}$$

This should be no surprise. With two equal resistance across the voltage source, it is obvious that one-half of the supply of voltage will be across each resistor.

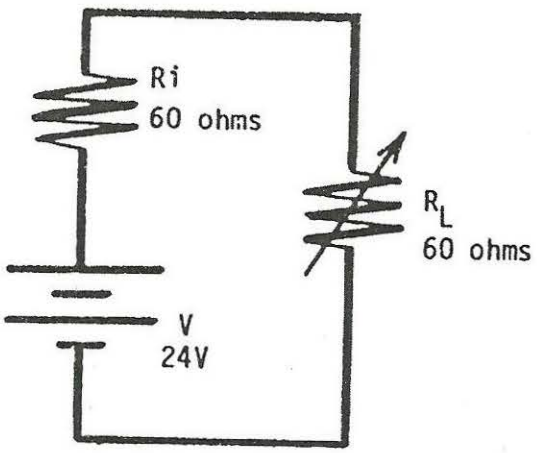


Figure 4-4

The power dissipated by R_L is

$$P_L = \frac{V^2_L}{R_L}$$

$$= \frac{12^2}{60}$$

$$P_L = 2.4 \text{ WATTS}$$

Be very certain that you know the relationships between the polarities applied to the leads on transistors, FETs and even vacuum tubes. For example, the base of a PNP transistor must be negative with respect to its emitter, but it is **positive with respect to its collector!**

Keep in mind that questions on D-C voltages are often given as part of a circuit question. Here is an example:

Figure 4-5

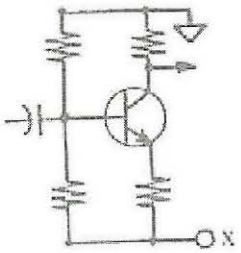


Figure 4-5

SAMPLE CET TEST QUESTION

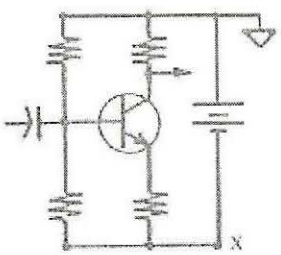
For the NPN transistor circuit in Figure 4-5, the polarity at point x should be:

(1) negative

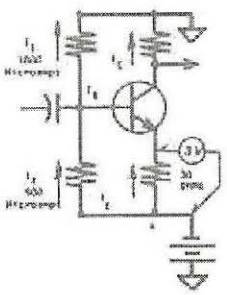
(2) positive

ANSWER; This is not necessarily the transistor that you will be given in the test. You may see a JFET or a MOSFET instead of the simple bipolar transistor shown in this illustration. In any case, the procedure for answering the question is to complete the circuit by drawing the voltage source neccssary to operate the device. This is done in Figure 4-6.

Figure 4-6



4-7.



Note that the voltage source is drawn between point x and the ground point. As shown, the positive side of the voltage source must go to the collector. Therefore, the voltage that goes to the emitter must be a negative voltage. This voltage would be connected from point x to ground a s shown in Figure 4-7. The answer to the question is (1)

You may be asked to find the values of D-C voltages or currents in circuits. The problem usually requires a use of Ohm's Law. A knowledge of Kirchoff's Laws may also be needed.

Current Law. The algebraic sum of the currents at any point in a circuit must be zero. Input currents are usually considered to be positive and output currents are usually considered to be negative.

Voltage Law. The algebraic sum of the voltages around any closed loop is equal to zero. Voltage drops are usually considered to be negative and voltage rises are positive.

SAMPLE CET TEST QUESTION

What is the value of collector current for the circuit of Figure 4-7?

(1) 99.1 mA

(2) 199.1 mA

(3) 299.1 mA

(4) 399.1 mA

ANSWER; The emitter current I_E is calculated by Ohm's LAW:

$$I_E = V/R$$

$$= 3 \text{ volts}/30 \text{ ohms}$$

$$I_E = 0.1 \text{ amps}$$

or

$$I_E = 100 \text{ mA}$$

The base current can be expressed in milliamperes

$$I_B = I1 - I2 = 1800 - 900$$

$$I_B = 900 \text{ microamperes} = 0.9 \text{ milliamperes}$$

Kirchoff's current law can be used to express the relationship between the currents in the transistor circuit.

$$I_E - I_B - I_C = 0$$

or $I_C = I_E - I_B$

$$= 100 - 0.9$$

The answer to the question is (1).

The D-C beta of the transistor may also be required in this type of problem. Remember that

$$\text{BETA (DC)} = h_{FE}$$

$$h_{FE} = I_C / I_B$$

$$= 99.1 \text{ mA} / 0.9 \text{ mA}$$

$$h_{FE} = 110$$

Also,

$$\text{Alpha (DC)} = h_{FB}$$

$$h_{FB} = I_C \backslash I_E$$

You may be asked a question that requires taking into consideration the tolerances of several resistors in a series-parallel combination.

SAMPLE CET TEST QUESTION

Three 12K resistors having a 4th color band of silver are connected in series-parallel combination. One of the resistors is connected in series with a parallel combination of the other two. An ohmmeter check across all three measures 16,300 ohms.

(1) one of the resistors has reduced in value.

(2) the resistors are ok.

ANSWER; (2) The lowest value for each of the two parallel resistors is 90% of 12,000 ohms, or 10,800. Their parallel value is 5400 ohms. In series with the other 12,000 -ohm resistor, which might also be at its lowest in-tolerance value (10,800 ohms) the total resistance of the current is

$$10{,}800 + 5400 = 16{,}200 \text{ ohms}$$

Therefore, the measured value of 16,300 is ok, being 100 ohms within the lowest limit of tolerance

A - C CIRCUITS

In the section marked A-C CIRCUITS you may be asked questions about the effect of inductors and capacitors on the flow of alternating current. You will also be asked about this effect on alternating current at different frequencies.

Remember: **capacitors tend to pass high frequencies and reject low frequencies; inductors tend to pass low frequencies and reject high frequencies.**

Figure 5-1 shows some schematic samples of tuned circuits. Series resonant circuits, like the one in Figure 5-1 (a), will pass one frequency or band of frequencies and reject all others. Parallel tuned circuits, which are also called **traps** as shown in Figure 5-1 (b), will reject one frequency or one band of frequencies and pass all others.

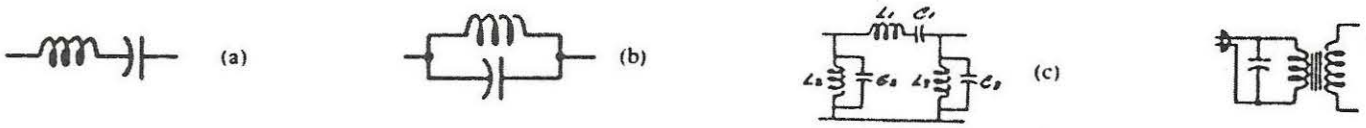


Figure 5-1

A **band-pass** filter made with tuned circuits is shown in Figure 5-1 (c). All of the frequencies - EXCEPT THE FREQUENCY TO BE PASSED - will be shorted to ground through trap circuit C2 and L2. Series-tuned circuit C_1 and C_2 is designed to pass the band of frequencies desired. Any frequencies that happen to get through will be grounded by C3 and L3 in this circuit.

A **band-reject**, or band-rejection filter would have series circuits in place of the traps, and a trap in place of the series-tuned circuit.

The circuit in Figure 5-1 (d) shows a capacitor (C) across the primary winding on a power-supply transformer. The purpose of that capacitor is to remove high-frequency transients so that they will not get into the power supply circuits. In that sense, capacitor C is a filter circuit because it shorts the high frequencies around the primary. The capacitor is like an open circuit to the low 60-Hz frequency normally operating in the transformer.

You might be asked about the relationship between RMS, peak, and average values for a pure sine wave. These questions are usually related to some type of oscilloscope display which requires you to be able to calculate the peak voltages and the frequency of a signal. The following sample problem is given with respect to Figure 5-2

SAMPLE CET TEST QUESTION

What is the frequency of the signal displayed in Figure 5-2?

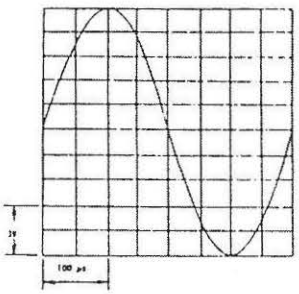
(1) 1500 hertz

(2) 2000 hertz

(3) 2500 hertz

(4) 3000 hertz

Figure 5-2



ANSWER; Each horizontal square represents a period of 50 microseconds. The complete cycle is 8 squares wide or, 50 x 8 = 400 microseconds wide . This means that the period (T) of the wave is 400 microseconds

$$f = 1/T$$

$$= 1/(400 \times 10^{-6})$$

$$f = 2500 \text{ Hz}$$

The answer to the question is (3).

SAMPLE CET TEST QUESTION

The RMS value of the sine-wave voltage displayed in Figure 5-2 is:

(1) 5.0 V

(2) 5.3 V

(3) 5.6 V

(4) 6.0 V

ANSWER; Each vertical square represents 1.5 volts. There are 5 squares between the center line and peak, so the peak voltage is

$$5 \times 1.5 = 7.5 \text{ V}$$

$$5 \times 1.5 = 7.5 \text{ V}$$

The RMS voltage (V) is 0.707 times the peak value $(V)_{MAX}$

$$V = 0.707 \times V_{MAX}$$

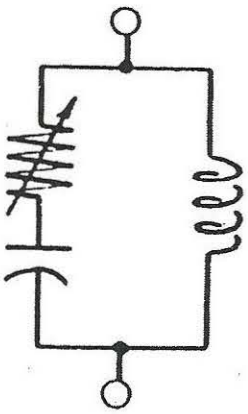
$$= 0.707 \times 7.5$$

$$= 5.3 \text{ volts}$$

The answer to the question is (2)

Figure 5-3 illustrates a circuit that causes considerable trouble for technicians in the CET test This is a tuned parallel trap. The reason it presents a problem is that in many basic courses technicians are told that the frequency of the series tuned circuit is not affected by the value of resistance connected in that circuit. Technicians are sometimes taught Q is the only thing that is affected.

Figure 5-3

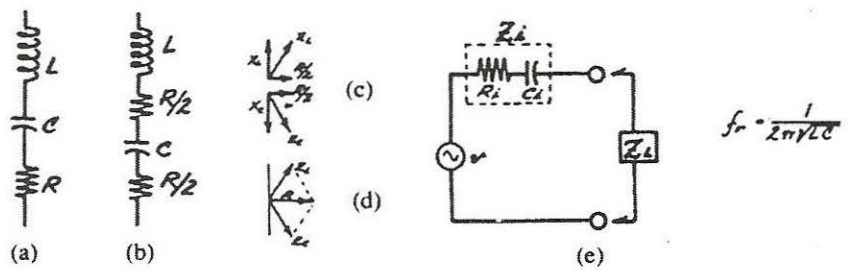


In the circuit of Figure 5-3, a resistor is connected in series with the capacitor and its **effect cannot be ignored.** As a matter of fact, this circuit **can be tuned by adjusting the variable resistor.** The variable resistor could also be connected in series with the inductor to get a similar result, Or, there may be a resistor in both branches. Tunable traps have been designed this way in TV receivers, and it is necessary for the technician to know that **resistance can affect the frequency of the parallel-tuned circuit.**

Review of Series-Tuned Circuit Theory

The illustration for series resonance is given in Figure 5-4.

Figure 5-4



In a series-tuned circuit resonance occurs when the inductive reactance equals the capacitive reactance. In other words, $X_L = X_C$.

Figure 5-4 (a) shows a series-resonant circuit. Assume that an AC generator is connected across this circuit producing a voltage at the resonant frequency. The circuit is redrawn in Figure 5-4 (b) with the resistance divided equally between the L and the C sections.

The phasor graphs for the circuit components are shown in Figure 5-4 (c). Since this is a series circuit, the same amount of current flows through each component. Therefore, you could multiply each resistance and reactance value by the circuit current. That in turn would convert each of them into voltage phasors.

The following point cannot be overemphasized. **The phasors for X_L and X_C are NOT equal!** Yes, they **do** cancel. Yes they have equal magnitudes (because the circuit is in resonance and $X_L = X_C$). But, they are NOT equal.

THE TWO PHASORS ARE EQUAL IF -- AND ONLY IF --
THEY HAVE EQUAL MAGNITUDES AND DIRECTIONS !!

Figure 5-4 (d) shows the resultant phasors on a set of X - Y coordinates The resultant is the pure resistance phasor marked 'R'.

Suppose you want to get the maximum possible power from the generator of Figure 5-4 (e). Do you make the load impedance **equal** to the internal impedance of the generator. The answer is NO ! If you connect a resistor and capacitor across the output (equal to the internal R and C), you will NOT get maximum power !

Actually, to get maximum possible power you connect an **inductor** and **resistor** across the load, so that the inductive and capacitive reactances are equal and the resistance values are equal. In other words, the load impedances must be **conjugates.** That's why we say the impedances are **matched**, not equalled.

When resonance occurs in the circuit of Figure 5-4 (e). the power-factor of the generator is 1. That means the voltage and the current are **in phase.** That means the **only limit to the current flow is R !** That is why you have to be very careful not to destroy an AC generator by putting a series-resonant circuit across its terminals.

The equation for the resonant frequency of a circuit is given in Figure 5-4 (e). From this equation it is obvious that **reducing** the value of either L or C will **increase** the resonant frequency of a series-tuned circuit.

SAMPLE CET TEST QUESTION

Pushing the turns of wire closer together in a series-tuned circuit will:

(1) increase the resonant frequency.

(2) decrease the resonant frequency.

ANSWER; (2) Increasing L in the equation causes the value of f_r to decrease.

Review of Parallel-Tuned Circuit Theory

You will remember that the reciprocal of resistance is conductance (G); the reciprocal of reactance is susceptance (B);, and the reciprocal of impedance is admittance (Y), In a parallel-tuned circuit,**the resonant frequency is obtained by setting the susceptances equal ($B_L = B_C$).** The concept of parallel resonance is given in Figure 5-5.

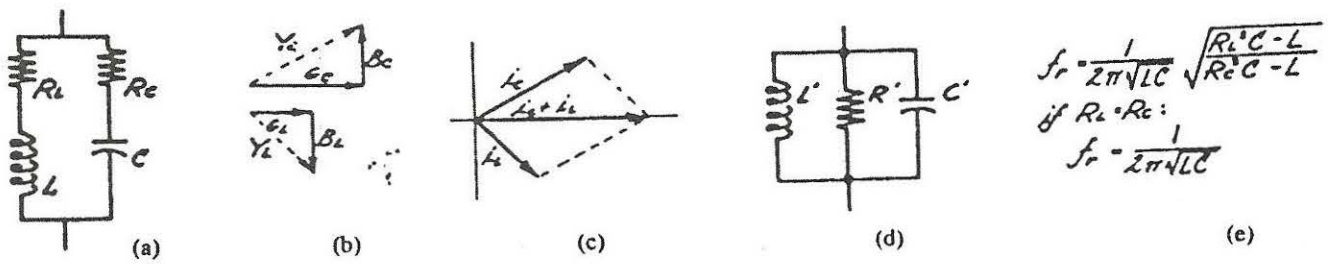


Figure 5-5

The general case parallel-resonant circuit is shown in Figure 5-5 (a). The values of components are not given, but it is assumed that R_L and R_C have sufficient resistance that their effect on resonance cannot be ignored.

An example of a phasor representative for the parallel- resonant circuit is shown in Fig 5-5 (b) In this diagram $B_L = B_C$, but the admittances of the two branches are NOT equal. (Y_L does not equal Y_C), Even so, the circuit is in resonance.

Since the voltage is the same in all parts of a parallel circuit, that voltage can be divided by Y_C and Y_L to get the current phasors shown in Figure 5-5 (c) This very important illustration shows that **in a parallel-resonant circuit the currents in the branches do NOT have to be equal !**

Notice that any circuit like the one in Figure 5-5 (a) can be redrawn as shown in Figure 5-5 (d). The circuits are equivalent because they present identical impedances (and admittances) to the generator.

The resistance R' in Figure 5-5 (d) is called a **swamping resistor.** The lower the value of R the lower the Q and the more broadly the circuit will tune.

The equation in Figure 5-5 (e) is the general-case equation for the parallel resonant frequency of the circuit in Figure 5-5 (a). NOTE THAT THE RESISTANCES IN THE BRANCHES AFFECT THE RESONANT FREQUENCY OF THE CIRCUIT ! However, if these resistances can be disregarded, then the **special case** equation can be used.

Table 5-1

	SERIES CIRCUIT	PARALLEL CIRCUIT
Impedance at Resonance	Minimum	Maximum
Generator Current at Resonance	Maximum	Minimum
Voltage Across Circuit at Resonance	Minimum	Maximum

TRANSISTORS AND SEMICONDUCTORS

It is presumed that you know the schematic symbols for the semiconductor devices used in electronics.

Also, be sure you know the operating voltage for the devices, especially the transistors. You may be asked about common-emitter, common-collector, or common-base configurations. As a reminder, at the end of this chapter are included comparisons of transistor and MOSFET configurations..

SAMPLE CET TEST QUESTION

In a pnp transistor, the base must be

(1) positive with respect to the collector.

(2) negative with respect to the collector.

ANSWER; Choice (1) is correct.

Unfortunately, the symbolism for some semiconductors is not standardized in the industry. Different manufacturers may show variations of the symbols according to their own drawing specifications. Figure 6-1 shows examples of variations.

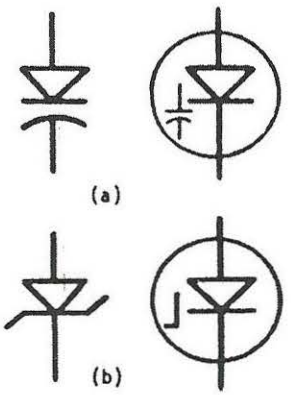


Figure 6-1

Figure 6-1 (a) shows two different ways of representing a **varactor diode**. As you know, this is a voltage-variable capacitor. Figure 6-1 (b) shows two different ways of drawing a zener diode.

Figure 6-1

A question you might be asked about the components in Figure 6-1 is what do they have in common? The answer is **both are operated with a reverse voltage.** In other words, to get these devices into operation, the cathode must be connected to the positive side of the source.

It is necessary for reverse **current** to flow in the zener diode but not in the varactor diode.

You should be familiar with the symbols of an operational amplifier, as shown in the examples in Figure 6-2. The negative sign on one of the

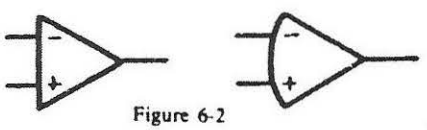


Figure 6-2

input terminals means that any signal voltage delivered to that terminal will be inverted 180^0 at the output. The non-inverting terminal is shown with a positive sign. These plus and minus signs have nothing to do with the power-supply connection to the operational amplifier. Normally, when the op amp is shown in a circuit, the power supply connections are not included.

Operational amplifiers have a differential input and a very linear rolloff. The most common connection is the inverting amplifier in Figure 6-3. The voltage gain of this circuit is given by the equation

$$A_V = - \frac{R_f}{R_i}$$

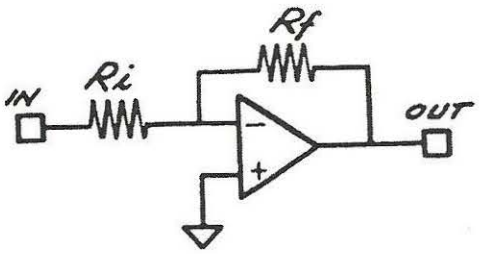


Figure 6-3

(The negative sign shows that it is an inverting connection.) For the non-inverting amplifier of Figure 6-4 the voltage gain is:

$$A_V = 1 + \frac{R_f}{R_i}.$$

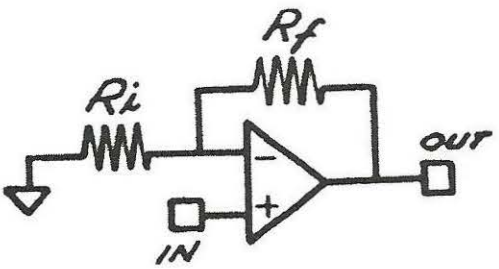


Figure 6-4

In addition to the symbols for the semiconductor devices, you should have a basic understanding of how they are rated. Diodes are rated according to their forward current and allowable peak inverse voltage.

Figure 6-5 shows a circuit that might be used to test your knowledge of diode specifications. In this circuit, the two diodes are connected in series. The resistors across the diodes assure that there will be an even distribution of reverse voltage across each diode. Capacitors are sometimes connected across each series-connected diode to assure an equal reverse-recovery time. So, they help protect the diodes from the effects of transient voltages.

SAMPLE CET TEST QUESTION

Diodes are connected in series as shown in Figure 6-5

to

(1) increase their current ability.

(2) increase their peak inverse voltage rating.

ANSWER; When diodes are in series, the reverse voltage divides between them. Since the reverse-leakage resistance may be slightly different, resistors are used to equalize the reverse-voltage drops. The answer is (2).

Diodes are connected in parallel to obtain a higher current rating. Series starting resistors are connected as shown in Figure 6-6 to assure that both diodes will conduct.

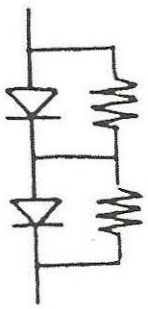


Figure 6-5

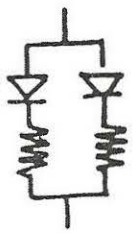


Figure 6-6

A general class of semiconductors having four layers of semiconductor material are known as thyristors. Examples of thyristors are the PNPN diode, the bilateral switch or diac, the SCR (silicon controlled rectifier), and the triac. CET tests often include questions on thyristors, especially on the SCR and the triac.

The **PNPN diode** consists of four layers of semiconductor material. These are alternative layers of P-type and N-type

material placed together. This gives three junctions. Typically, it's operated so that one end of P-type material (its anode) is at a higher potential than the other end (its cathode) of N type material. Then, its first and third junctions are forward biased and its center junction reverse biased, there is little current flowing. As the forward bias voltage is increased slowly the current flowing increases until the **breakover, or firing voltage,** is reached and the flow of current sharply increases. The PNPN diode is often treated as a switch that is OFF at voltages below the firing voltage and ON above it.

The **bilateral switch** is similar to the PNPN diode, but it has two semiconductor diodes facing in opposite directions and they are attached to each other in parallel. The bilateral switch has the same action as the PNPN diode but it responds identically for both the positive and negative bias voltage.

The **SCR, or silicon-controlled rectifier** is a four-layer device with four connections. There is one connection to each of the outer ends-- the anode and the cathode -- and one connection to each of the inner two layers of semiconductor material. The connection to the N-type material near the anode is called the anode gate and the connection to the P-type material near the cathode and is called the cathode gate. Some SCRs are constructed without the anode gate connection, making the SCR a three-terminal device. as shown in Figure 6-7. The terminals are the anode, the cathode, and the gate.

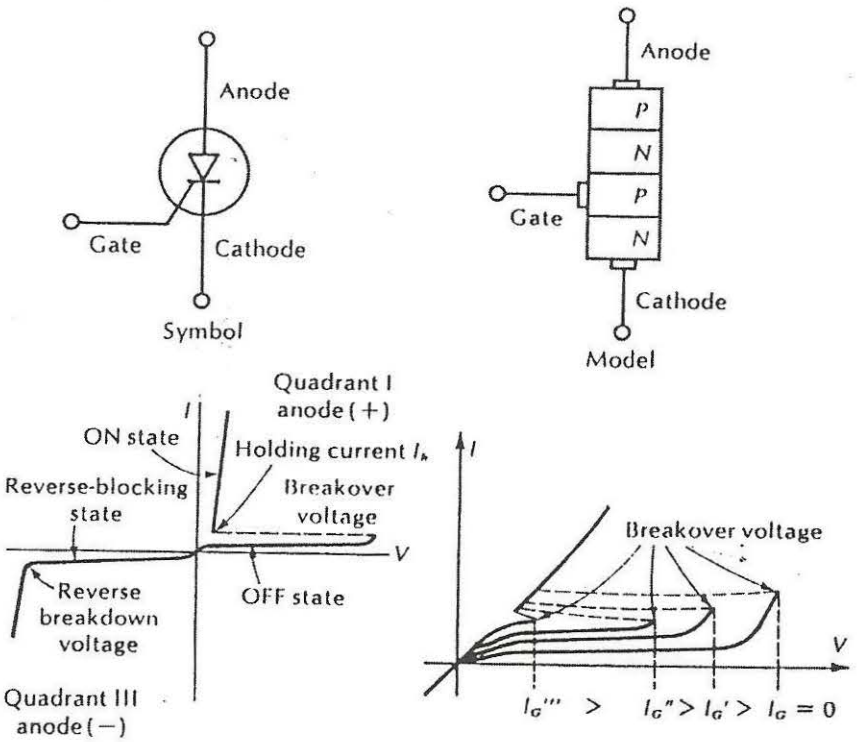


Figure 6-7

Like the PNPN diode, the SCR is used to sharply start conducting when the voltage exceeds a given level. When a positive pulse is applied to the gate of the SCR it will conduct and continue to conduct even if the gate voltage is removed. as long as the anode is positive. When the positive voltage is removed

from the anode, the SCR stops conducting. With appropriate bias of the gate voltage, the breakover voltage can be closely controlled.

The basic current path for the SCR is from the negative side of the voltage supply, to the cathode, through the SCR, to the anode, the load, and back to the positive side of the power source. If the voltage applied to the gate is negative or below the breakover voltage, the SCR will not conduct, but if the gate voltage becomes sufficiently positive, the SCR will conduct. The output of the SCR is a DC voltage since with AC applications, it conducts only on half cycles. Therefore, the load receives a reduced voltage.

The SCR is used in many well-known circuits such as light dimming, controlling AC power to a load, and so on. Sometimes this reduced power is a disadvantage. SCRs are available with different ratings, with various response curves for different breakover voltages.

In some applications a reverse bias is applied to the gate or, on AC applications, phase firing is used to prevent firing from noise.

In phase-firing of SCRs, the phase of the positive half cycle of the applied sine waves can control the amount and timing of the gate current and, therefore, the output current of the SCR. SCR switching waveforms are shown in Figure 6-8. The conduction angle and times for the SCR are shown for 0-, 45-, 90-, and 135-degree conduction angles measured from the positive-going transition of the input wave. The earlier the SCR is triggered, the more power is delivered to the load.

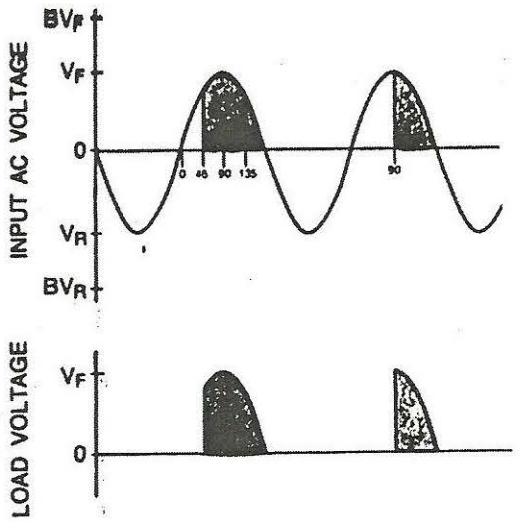


Figure 6-8

The **Triac** takes care of the reduced output of the SCR. It consists of the equivalent of two SCRs in a single package operating back-to-back. as shown in the model of Figure 6-9. Its characteristic curve, as shown, is a bilateral curve. The gate can

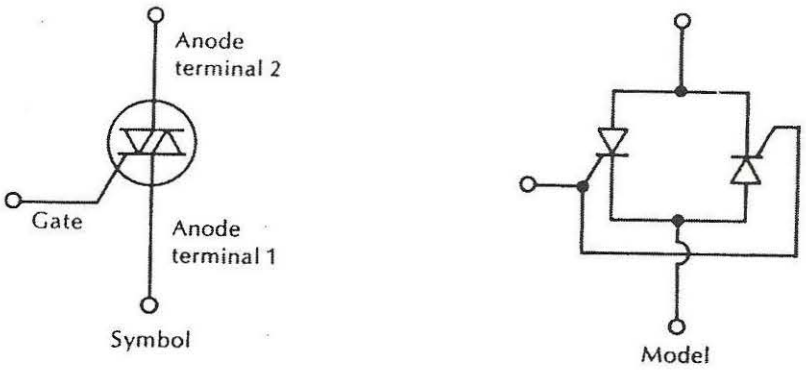
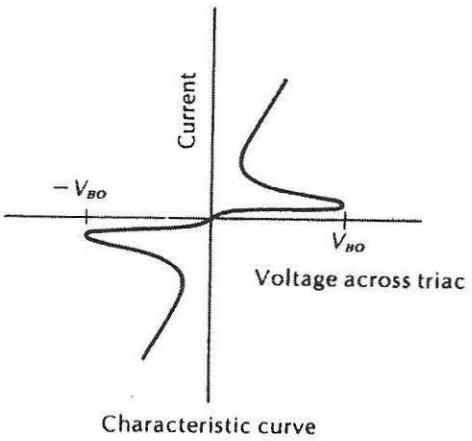


Figure 6-9



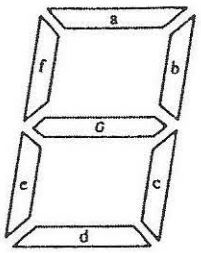
turn on each SCR alternatively, providing full-wave output.
Triacs are used as power switches in electronic relays.

It is recommended that you do some additional study of the SCR, the Triac, and the diac, especially with regard to the advantages and disadvantages of the different methods of firing, the problems of interference and noise, and the typical voltages and currents for operation. The simplest and most used firing arrangement is SCR phase firing. In some cases the SCR gate is reverse-biased to prevent unwanted firing from interference and noise. Changing the firing angle changes the output current.

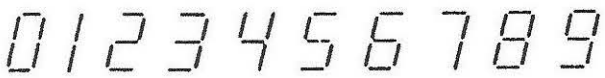
Seven-Segment Displays

Two of the most-used types of seven-segment displays are LEDs (light-emitting diodes) and LCDs (liquid crystal displays). The LED type uses seven separate LEDs to make up the segments for the display and adds a segment if a decimal point is needed. The LCD type of display consists of two sheets of glass with a liquid in between that can be electrically polarized to allow or inhibit the passage of light. The LCD type does not produce any light of its own, but must be externally illuminated somehow to display figures. The external illumination may be room light, daylight, or background light.

The seven segment display can display numbers 0 through 9 and many letters of the alphabet. Their main use, however, is in displaying numbers. In Figure 6-10, the segments are identified as a through g. In order to display the number 3, for example, segments a, b, c, d, and g would be lighted. To display the numeral 9, the segments a, b, c, d, f, and g would be illuminated, and so on.



Identification Of Segments Of
SEVEN-SEGMENT DISPLAY



HOW SEGMENTS ARE USED FOR NUMBERS

Figure 6-10

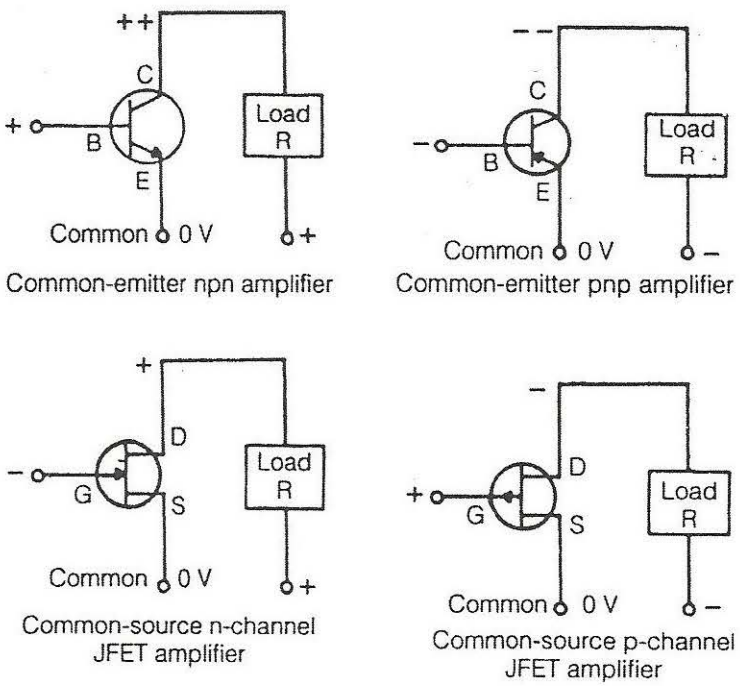


Figure 6-11

Transistor Relative Voltages

Typical relative DC operating voltages and their polarities for some transistors, FETs and MOSFETS are shown in Figures 6-11 and 6-12. These voltages shown are with respect to the emitter or source (S). You should study these and other sources for information on transistor relative voltages. Be prepared for some questions on these in the CET test.

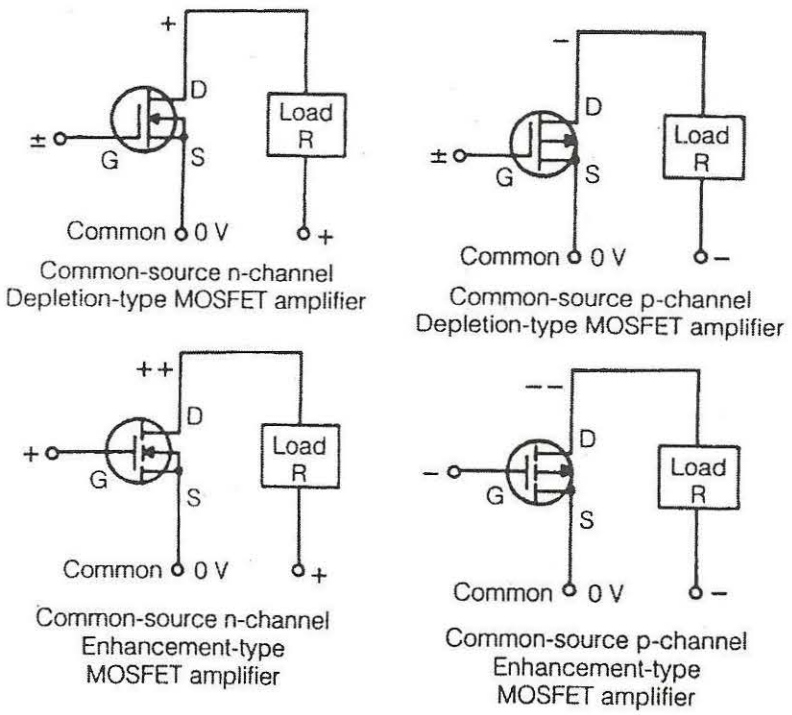


Figure 6-12

ELECTRONIC COMPONENTS AND CIRCUITS

At one time the subject of diodes could be covered in one chapter of a beginning electronic textbook. However, semiconductor diodes have made this subject so widespread that it is difficult for technicians to keep track of the newer types. There are several diodes, however, that the technician is expected to be familiar with when he takes the Associate-Level test. Schematic symbols for these diodes are shown in Figure 7-1. A brief discussion of these will be given here.

The varactor diode is sometimes referred to as a **voltage-variable capacitor** (also known by the trade name **Varicap**). It is a semiconductor junction diode connected with reverse bias. This causes a depletion region at the junction that acts like the dielectric of a capacitor. Basically, the greater the reverse bias, the greater the depletion region. Increasing the reverse bias is equivalent to moving the plates of the capacitor further apart, and that REDUCES the capacitance. Varactors are mostly used for tuning, and in parametric amplifier circuits.

Zener diodes are connected with reverse bias and they are used primarily for voltage regulation. The voltage across the zener diode is constant (or nearly so) even though there may be a relatively wide change in current through that diode. Zener diodes are used in applications where a constant voltage, under varying current conditions, is required.

Diacs are also known as three layered diodes. They are an example of **breakover devices** – which means that they will not conduct until the voltage across them reaches a certain minimum (breakover) value. Diacs are bilateral devices. In other words, they will break over in either direction.

Shockley diodes, which are also called four-layer diodes, are also breakover devices. They have a characteristic in one direction that is similar to the diac, but if you reverse the potential across a Shockley diode it will conduct without a breakover.

Diacs are often used at the input of an SCR that is used in a power regulating circuit. The diac will not permit the SCR gate voltage to be delivered until the input to the diac has reached a certain minimum breakover voltage value.

Do not confuse Shockley diodes with Schottky diodes. The latter is made with a **metal/semiconductor** junction. It has a very low forward voltage drop during conduction, so, its characteristic is similar to that of an ideal diode.

Tunnel diodes are used as very fast switches, and as oscillators. They have a negative-resistance characteristic similar to the one in a tetrode characteristic curve.

Light emitting diodes (LED's) and light activated diodes are optoelectronic devices. The typical forward voltage drop across an LED is 1.6V.

Tubes

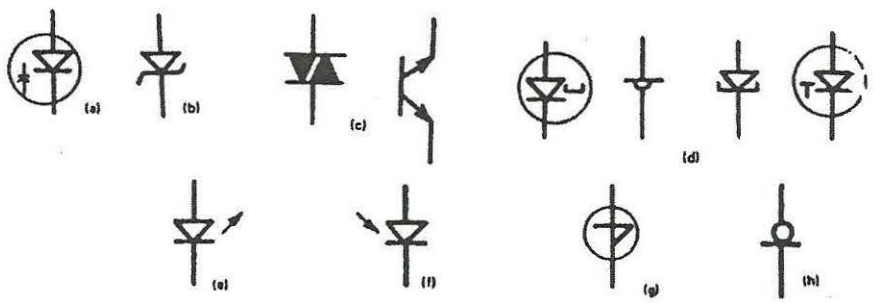
Very little is asked about tubes in the Associate-Level CET test. It is important to know that triodes have an advantage over tetrodes and pentodes because of their low noise. You can remember that the greater the number of elements in a vacuum tube the greater the amount of noise presented to the system.

Pentodes are noisier than triodes, but they have the advantage that they do not have a large amount of plate-to-cathode and plate-to-grid capacitance. Therefore, they are more useful at high frequency.

(a) Varactor Diode*
(b) Zener Diode
(c) Diac
(d) Tunnel Diode

(e) LED
(f) Photo Diode
(g) Four-Layer Diode
(h) Constant-Current Diode

Figure 7-1



Tetrodes also have a lower interelectrode capacitance than triodes, but they have the disadvantage that there is a negative resistance layer in their characteristic curve. This negative resistance layer acts very much like the negative resistance section in a tunnel diode characteristic curve.

Bipolar Transistors

Bipolar transistors are more often called NPN and PNP types. They are characterized by low D-C operating voltages. This is important because it makes large values of coupling capacitance permissible in audio amplifiers. The input impedance of bipolar transistors is characteristically low, and since **current** must be delivered to the base, they require more operating power than JFET's and MOSFET's.

SAMPLE CET TEST QUESTION

In the circuit of Figure 7-2 an electrolytic capacitor is used for coupling the signal between Q_1 and Q_2. Which of the following statements is true?

(1) Leakage of that electrolytic capacitor will certainly destroy Q_1. So it should not be used.

(2) Leakage of the electrolytic capacitor will certainly destroy Q_2. So it should not be used.

(3) Electrolytic capacitors will not pass the higher audio frequencies, and therefore, the capacitor could not be used in an audio system.

(4) The electrolytic capacitor is okay to use, and its use is made possible by the low operating voltages of bipolar transistors.

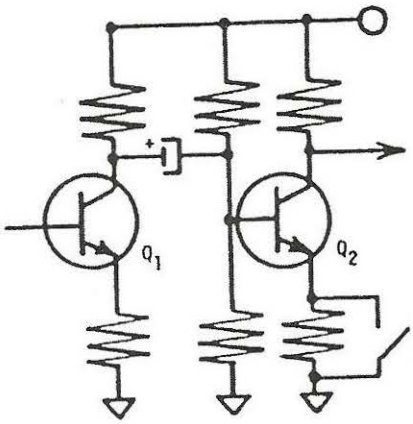


Figure 7-2

ANSWER: Choice (4) is correct. There would be an excessive leakage if the operating voltages were high. You will see electrolytic capacitors used in this position in audio systems.

Be sure you have a good understanding of the polarities of the operating voltages necessary for using PNP and NPN transistors. Remember that in the NPN transistor the base is positive with respect to the emitter but negative with respect to the collector. Likewise, in a PNP transistor the base is negative with respect to the emitter but positive with respect to the collector.

Field Effect Transistors

Field effect transistors have the advantage (over bipolars) of a high input impedance. This means that the field effect transistors do not load the preceding circuit; and, it is not necessary to draw signal current in order for the device to operate. As with bipolar transistors, you must have a good working knowledge of the D-C voltages necessary for putting the field effect transistors into operation. This includes junction field effect transistors (JFETS), MOSFETS, enhancement MOSFETS, depletion MOSFETs and V-MOS devices.

It is likely that you will be asked to identify one or more of the symbols for these devices. Always keep this fact in mind: **the arrow in semiconductor symbols always points toward the N region and away from the P region.**

SAMPLE CET TEST QUESTION

Observe the symbols in Figure 7-3. Which of these symbols is for a P-channel JFET?

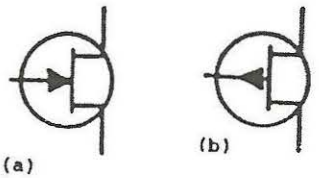


Figure 7-3

(1) The symbol shown in Figure 7-3(a)

(2) The symbol shown in Figure 7-3(b)

ANSWER: Choice (2) is correct. The symbol shown in Figure 7-3(b) is for a P-channel JFET. It has the arrow pointing away from that portion of the symbol which represents the channel, and therefore, it is a P-channel device.

Some Circuits You Will Be Asked About

You are almost certain to be asked about power supply circuitry. You need to know the characteristics of power supplies, and be able to identify the different rectifiers. Specifically the **half-wave rectifier, full-wave rectifier, bridge rectifier, half-wave doubler** and **full-wave doubler** are rectifier circuits that you are likely to encounter.

Remember that the ripple frequency of half-wave rectifiers is always equal to the frequency of the input power. The input power frequency may not always be 60 hertz, so you must make sure that you are answering the question for the specific input power frequency of the device under consideration. As an example if the input power has a frequency of 400 hertz, then the ripple frequency will be equal to 400 hertz when a half-wave rectifier is used. For a full-wave rectifier, for a 400-hertz input frequency, the ripple frequency will be twice as great, or 800 hertz.

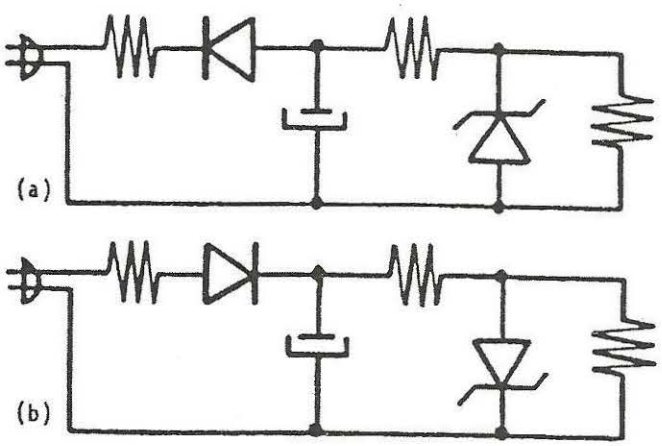


Figure 7-4

Be sure you understand how power supplies are used to produce both positive and negative output voltages.

You might also get a question on an unloaded rectifier power supply. If it has only a filter capacitor, and it is operating without a load, the output voltage will be equal to the peak AC voltage.

SAMPLE CET TEST QUESTION

Consider the two illustrations in Figure 7-4. Which of the following statements are true?

(1) Neither circuit will work properly.

(2) Both circuits will work properly.

(3) The circuit in (a) will work properly but not the one in (b).

(4) The circuit in (b) will work properly but not the one in (a).

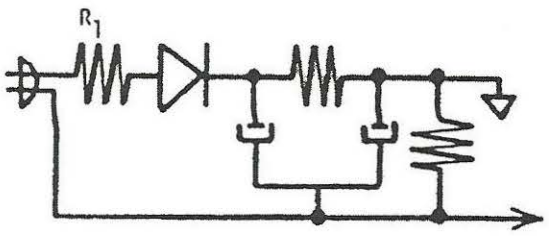
ANSWER: Choice (1) is correct. In both circuits the zener diode is forward biased. Therefore, it cannot operate properly. Since that diode is forward biased, the voltage drop across it is only 0.7 volt. Certainly this would be unsatisfactory for a power supply that is operating with an input voltage of 115 volts AC.

In addition to this, the power supply shown in Figure 7-4(a) has a negative output voltage **and the electrolytic capacitor is incorrectly connected into the circuit.** That capacitor will be destroyed after a few cycles of operation.

SAMPLE CET TEST QUESTION

Consider the half-wave rectifier circuit of Figure 7-5. What is the purpose of R_1 in this circuit?

Figure 7-5



(1) Resistor R_1 is used to improve the filtering of the rectifier output.

(2) Resistor R_1 is used to prevent burnout of the diode during the charging of the filter capacitors.

(3) Resistor R_1 is incorrectly drawn in this circuit. It should be on the right side of the diode.

(4) Resistor R_1 has no purpose in this circuit and should be eliminated for improved performance.

ANSWER: Choice (2) is correct. Resistor R_1 is known as a **surge-limiting resistor.** It usually has a value of only a few ohms. Its purpose is to limit the charging current through the diode when the circuit is first energized. This charging current comes from charging the capacitors to a value that is approximately equal to the D-C output voltage of the power supply circuit.

On the first half-cycle the capacitors are charging – especially the input capacitor which is connected directly to the cathode of the diode. The amount of charging current can be very, very high and can destroy the diode in a few half cycles.

Circuit Configuration

Another thing to have clearly in mind before you take the test is the comparison between the emitter follower, common-base, and common-collector circuits. Remember that the emitter follower has a high input impedance and a low output impedance. In this sense it is exactly like a cathode follower or source follower. It always has a voltage gain that is less than 1.0.

Common-base circuits are normally used for high-frequency applications and in this sense they are similar to grounded-grid and common-gate amplifier circuits.

The common-emitter circuit is sometimes called the **conventional amplifier.** It is equivalent to the common-cathode and the common-source circuits. It has the characteristics of a high voltage amplification and fairly high power amplification.

Remember, also, that only the common-emitter circuit causes a 180-degree phase shift between the input and output signals.

SAMPLE CET TEST QUESTIONS

Consider the circuit of Figure 7-6(a). Which of the following statements is correct?

(1) The output signal is in phase with the input signal.

(2) The output signal is 180 degrees out of phase with the input signal.

ANSWER: Choice (1) is correct. This is a typical emitter follower bipolar transistor amplifier. So, there is no phase inversion.

Another thing you should remember about this circuit is that RE (the emitter resistor) is NOT a bias resistor. The purpose of that resistor in bipolar circuits is to increase the circuit stabilization against temperature changes. Also, it limits the circuit's tendency to oscillate at very high gain.

What should the polarity of the voltage at point x be in the circuit of Figure 7-6(b)?

(1) The voltage of point x should be positive.

(2) The voltage at point x should be negative.

ANSWER: Since this is a PNP transistor it requires a negative voltage on the collector with respect to the voltage on the emitter. Therefore, choice (2) is correct.

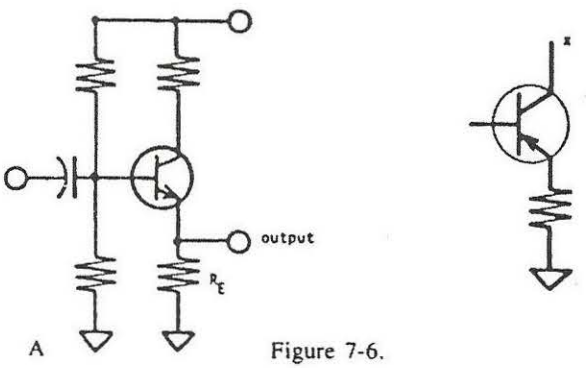


Figure 7-6.

How much voltage would you measure across the base-emitter junction of a silicon transistor operating at class A?

(1) OV (2) 0.2 V (3) 0.6 V (4) 3.6 V

ANSWER: Choice (3) is correct. A silicon transistor is forward biased with 0.6 V as the base emitter bias. A germanium transistor (little used these days) is forward-biased with 0.2 V across the base and emitter.

Switching Power Supply

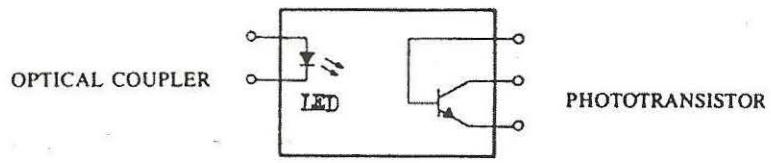
You should be familiar with the switching power supply, or switching-regulator power supply.

One of the disadvantages of rectifier power supplies operating off the 60-Hz power line, is that the rectified DC output of the power supply has a ripple-frequency of 60 or 120 Hz. This low ripple frequency requires relatively high-capacitance and large filter capacitors (and sometimes large filter chokes) to smooth the DC output voltage. The switching power supply gets around the problem of low-frequency ripple by taking the AC line voltage, rectifying it, and using a converter to change the DC voltage to a high-frequency AC voltage, such as 20 kHz to 100 kHz. This AC voltage is stepped up by a transformer to a desired voltage, which is then rectified and filtered. Although this entails a number of steps, the cost of filtering components is reduced, and so is their size. Another advantage is the higher efficiency of switching types, compared to analog types. Further, better filtering is accomplished at the higher rectified ripple frequency which is typically 20 kHz.

Optical Coupler

The opto-coupler, optical-isolator, or optical coupler consists of an LED (light-emitting diode) and a light-activated device in a common integrated-circuit, light-sealed package, as shown in Figure 7-7. The LED and photo transistor are physically and electrically isolated from each other.

Figure 7-7.



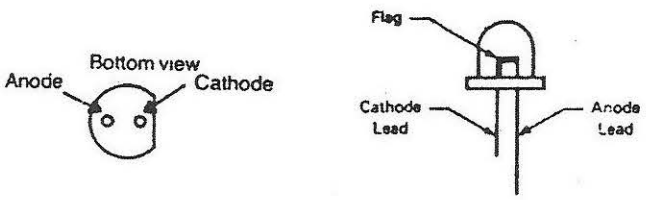
In practical use, the LED is part of one circuit, often a control circuit; and the photo transistor is part of another circuit, sometimes controlling the operation of a motor of other higher powered device. The opto-coupler in this application provides for a low-power sensitive circuit to control another circuit of higher power. Often the phototransistor is combined with a TRIAC which acts as a solid-state relay and can switch a high current load.

Light Emitting Diodes (LEDs)

Light emitting diodes of the type shown in the schematic of the optocoupler sometimes are found in questions for the apprenticeship test. They are widely used in digital, computer, and test instruments circuits. A top view of the LED is shown in Figure 7-8. Note that the plastic case of the LED has one flat side. The LED has two leads or conductors extending from the bottom. The lead closest to the flat side of the LED is a cathode lead; the other is the anode. The LED lights at its rated brightness when a positive voltage of between 1.5 and 2.0 V is applied to the anode. A current-limiting and voltage-dropping resistor is generally connected in series with the LED and a power supply of about +5 V in typical operation. The resistor drops the applied voltage to about 2.0 V. The LED intensity depends on the current through the LED which usually ranges between 10 mA and 100 mA.

Figure 7-8.

LIGHT-EMITTING DIODE (LED)



Differential Amplifier and Comparator

The differential amplifier consists of a pair of transistors that have identical or similar input circuits. The input circuits can be connected in a number of ways. One common way is to connect them to respond to the difference between the two voltages or currents. In this application the differential amplifier cancels or rejects those components of the two signals that are identical.

The rejection of like components of the two input signals is referred to as common-mode rejection. The CMRR, or common-mode rejection ratio, of a differential amplifier is an important specification.

A comparator is a circuit that compares two voltages, one applied to the inverting terminal and the other applied to the noninverting terminal of an open-loop operational amplifier. If the noninverting voltage is greater than the inverting voltage, the comparator produces a high output. If the inverting voltage is larger, the output is low. Thus, the output is either high or low, or yes or no. The exact amount of the difference does not matter to the comparator circuit.

Electronic Logic Circuits

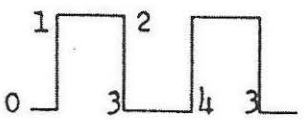
Logic Circuits

Logic circuits have become part of the everyday life of all electronics technicians. These circuits are found in great numbers in computers, and in increasing number in other electronic equipment including automation and control equipment, test instruments, TV tuners, VCRs, telephones, transmitters, etc.

A logic circuit, also called a logic gate, is basically a switching circuit. A switching circuit usually has one output condition for one or more input conditions. Most electronic logic circuits operate from digital signals that have two levels, either on or off. These levels may also be referred to by other related terms such as binary numbers 1 and 0, yes and no, high and low (HI and LO), go and no-go, and so on. In many logic circuits a range of voltages such as 2 to 5 V represents a high or 1, and a low or zero is represented by a voltage range of 0 to .8 volts. Voltages that are not within specified limits for logic 1 and logic zero are called **invalid.**

An example of a digital signal is shown in Figure 7-9. Digital signals are typically in the form of pulses, as shown. Digital signals are often called discrete signals. Analog signals are called continuous signals. The part of the digital signal shown representing 1 or high is that part between 1 and 2, in a positive or upward condition. The low or 0 part of the digital signal is the part between points 3 and 4, which is a negative or downward limit.

Figure 7-9. DIGITAL SIGNAL



There are also some logic circuits in which the voltages for 0 and 1 are negative. In these circuits, the 0 or low is more negative than the 1 or high condition.

Components in Logic Circuits

Logic circuits or logic gates may be made up of relays or switches or a combination of various electronic components. Examples are TTL (transistor-transistor logic), HTL (high-threshold logic), NMOS (N-channel metal oxide semiconductor) logic, PMOS (P-channel metal oxide semiconductor) logic, CMOS (complementary MOS), and ECL (emitter-coupled logic).

Boolean Expressions

To understand electronic logic also requires that you know a little about Boolean expressions or Boolean Algebra. Also, you might encounter a question on Boolean expressions

in a test. The concept of 1s and 0s are the tools of Boolean Algebra, and these 1s and 0s are referred to as variables. The language and symbols or notations of Boolean Algebra differ in some ways from the kind of mathematical language we are familiar with. For example, a bar over a letter, such as A, is read as "not A" or "A not." The following discussion on the four operations of Boolean Algebra discuss this not symbol, plus others. The operations are Equality, Complement, AND, and OR.

Equality. The equal sign (=) indicates that two or more variables are equal; for example, if we say A = B, and A = 1, then B also is equal to 1, or B = 1.

Complement. The complement is the opposite of a variable, and the complement of a variable is indicated by a bar over that variable. As mentioned before, the bar changes the variable into its opposite. For example, the complement of A is $\overline{A}$. Therefore, if A = 0 than $\overline{A}$ = 1; also, if A = 1, then $\overline{A}$ = 0. (In Boolean Algebra, 1 and 0 are the only two possibilities.)

AND. A dot (•) between variables indicates AND logic. Thus, you would read A • B = C as "A and B = C." The meaning of this expression is that C equals 1 – and only if – both A and B equal 1. It also follows that if A or B – or both A and B – equal zero, then C equals zero. (Note: AND logic such as A • B may also be shown without the dot AB or with parentheses A (B), or with a times sign A x B.)

OR. The OR operation is indicated by a plus + symbol. Thus, A + B = C is read as "A or B equals C," and means that C = 1 if either A or B is 1, or if **both** A and B equal 1.

Boolean Algebra is not confined to the three variables A, B and C, just used. For example, if there is a 4th variable D, then the following conditions occur:

A + B + C = D (D equals 1 except where A, B, and C all equal 0)

And $\overline{A}$ • $\overline{B}$ • $\overline{C}$ = D (D equals 1 only if A, B, and C all equal 0)

De Morgan's Theorem

A little more should be said about Boolean expressions. There are two expressions in particular that you should also know and these are referred to as De Morgan's Theorem. In these expressions, the terms on the left side of the expression are equal to the terms on the right side, so they are referred to as identities. The following two expressions compromise De Morgan's Theorem.

$$\overline{A + B} = \overline{A} \cdot \overline{B} \quad \text{and} \quad \overline{A \cdot B} = \overline{A} + \overline{B}$$

(An easy way to remember this is "Break the bar, and change the sign.") De Morgan's Theorem allows the use of as few chips as possible by substituting combinations of one gate for another.

Logic Gates

There are at least seven types of logic gates you should be familiar with in preparing for the Associate CET test. They are AND, OR, NOT, NAND, NOR, EXCLUSIVE OR, AND EXCLUSIVE NOR. You should also be familiar with the **truth tables** associated with each logic gate. A truth table gives the output condition that results from every type of input condition.

AND Gate

The symbol for logic AND is shown in Figure 7-10(a). Symbols are most often used in logic diagrams and in discussing logic circuits. We sometimes represent logic circuits with most

AND Gate

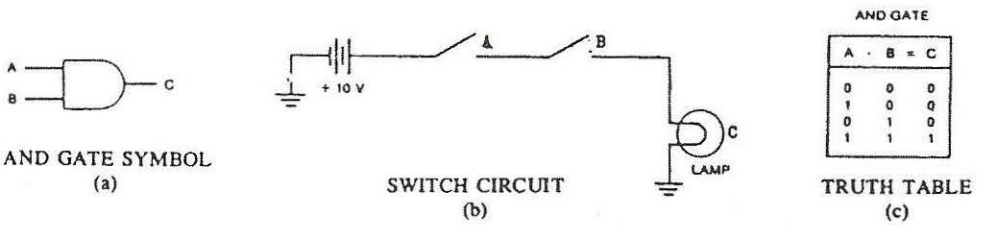


Figure 7-10.

conventional things such as switches as shown in (b). In an AND gate, both (or all) inputs must be HIGH or logic 1 in order to have the output HIGH, or logic 1. In the switch representation, both switches must be closed in order for the lamp to light. The truth table for the logic circuit is shown in (c). The truth table makes the following statements:

If A is 0 and B is 0, then C is 0.

If A is 1 and B is 0, then C is 0.

If A is 0 and B is 1, then C is 0.

If A and B are both 1, then C is 1.

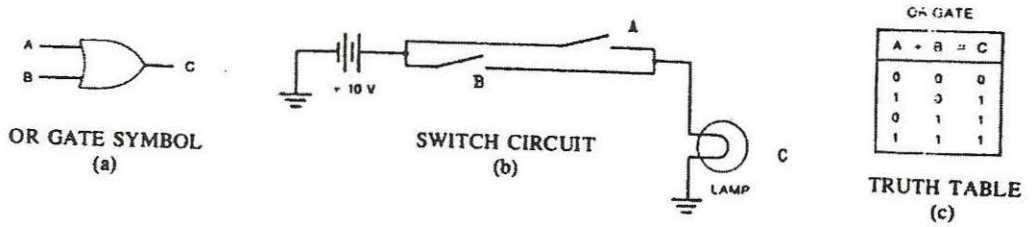
The AND gate may have two or many inputs. No matter how many, all of them must be logic 1 for the output to be logic 1. The AND gate is represented by the statement:

A AND B = C
Or
A • B = C
Or
AB = C

OR Gate

Like the AND gate, the OR gate has two or more inputs. But only one of the inputs need be logic 1 in order for the output to be at logic 1. The OR gate symbol and truth table are shown in Figure 7-11. Thus, in (a) if A or B is logic 1, or high, then C is high, or logic 1. Furthermore, if both A and B are 1, then C is 1.

Figure 7-11.



The OR gate can be represented by the switch circuit of (b), with switches identified as A and B, and the output C. With either switch A or switch B closed, or with both switches closed, the output indicator lamp would light (logic 1). The truth table for the OR circuit is shown in the statement representing logic OR is A + B = C, read as A OR B equals C.

NOT Gate or Inverter

A NOT gate has only one input. The output of the NOT gate shows the opposite of the condition applied at the input. Thus, if the input is logic 0, the output is logic 1; or if the input is logic 1, the output is logic zero. In Figure 7-12, the input is shown as A, and the output is shown as A, or not-A, or A-not. The relationship of inputs and outputs are also shown in Figure 7-12. The small circle at the right side of the NOT gate symbol indicates negation, or reversal, of the input condition.

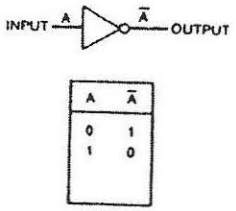


Figure 7-12. NOT GATE, OR INVERTER AND TRUTH TABLE

The NOT gate is also referred to as an Inverter – the input is inverted at the output. Sometimes you might see the triangle symbol without the not-circle. In that case the circuit acts as a buffer, or amplifier, which is sometimes used for separating circuits. A buffer has the same output as its input. If the input is 1, the output is 1; if the input is zero, the output is zero.

The statement representing the NOT gate is:

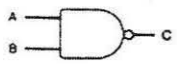
$A = \overline{A}$

If A is 0, then $\overline{A}$ is 1; and A = 1, then $\overline{A}$ = 0.

NAND Gate

In Figure 7-13 are shown the logic symbol and the truth table for the NAND gate. The symbol for the NAND gate is the same as that for the AND gate except that the NAND gate has the small negation or inversion circle at its output. NAND is read as "not AND."

Figure 7-13. NAND GATE AND TRUTH TABLE



NAND GATE

A	B	C
0	0	1
1	0	1
0	1	1
1	1	0

The output of a NAND gate is the reverse of what it would be if the gate were an AND gate, or, stated another way, the NAND gate gives the same results as an AND gate with a NOT gate connected at its output.

In the NAND operation the output is logic zero if, and only if, all the inputs are logic 1. Also, if one or some or all of the input conditions are logic 0, then the output is logic 1.

The NAND operation may be expressed as follows:

$$\overline{A \cdot B} = C \text{ or } \overline{A} + \overline{B} = C$$

It is important to note that $\overline{A \cdot B}$ is the same as $\overline{A} + \overline{B}$. But $\overline{A} + \overline{B}$ is not the same as $\overline{A + B}$; and neither is $\overline{A} \cdot \overline{B}$ the same as $\overline{A \cdot B}$.

NOR Gate

The output of the NOR gate is the inverse of the OR gate under identical input conditions. You could think of NOR meaning "not-OR." Figure 7-14 shows the logic symbol and truth table for the NOR gate. The NOR gate has the inversion circle at its output; otherwise it is the same as the OR symbol. Looking at the truth table, note that one or more true, or logic 1, inputs will produce a false, or logic zero output.

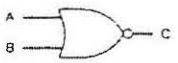
The NOR gate can be represented as:

$$\overline{A + B} = C$$

or

$$\overline{A} \bullet \overline{B} = C$$

Figure 7-14. NOR GATE AND TRUTH TABLE



NOR GATE

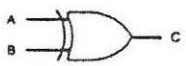
A	B	C
0	0	1
1	0	0
0	1	0
1	1	0

XOR and XNOR Gates

An exclusive-OR, or XOR, gate operates the same as an OR gate, except when both inputs are logic 1, then output is logic 0. The XOR symbol and truth table are shown in Figure 7-15. The only time there is a logic 1 output is when only one of the inputs is logic 1.

The exclusive-NOR, or XNOR gate, is the same as the NOR gate or logic comparator except that when two logic 1 inputs are present, the output is logic 1. The symbol and truth table for the XNOR gate is shown in Figure 7-16.

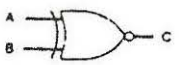
Figure 7-15. XOR GATE AND TRUTH TABLE



XOR GATE

A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

Figure 7-16. XNOR GATE AND TRUTH TABLE



XNOR GATE

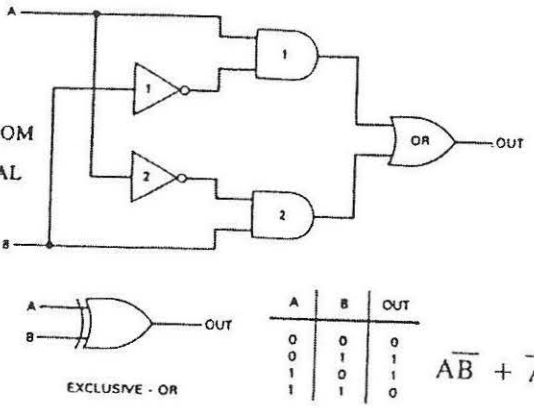
A	B	C
0	0	1
1	0	0
0	1	0
1	1	1

Combination Logic

Logic devices are frequently used in combinations. The types of gates and their arrangements depend on their application. Figure 7-17 shows a combination of three types of logic gates. Their arrangement makes up an XOR gate. The circuit shown consists of two NOT gates, two AND gates, and one OR gate. There are four possibilities for inputs A and B as shown by the truth table. Further study of XOR gates will be helpful in understanding the other conditions shown in Figure 7-17.

Figure 7-17.

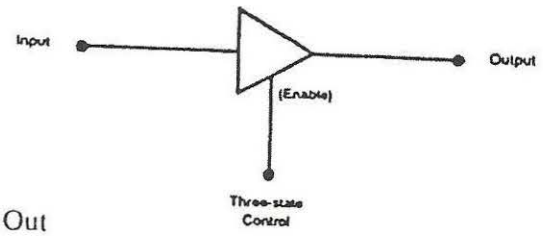
EXOR GATE FROM COMBINATIONAL LOGIC



A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

$A\overline{B} + \overline{A}B = Out$

Figure 7-18. TRI-STATE BUFFER



Three-State Devices

A tri-state buffer is shown in Figure 7-18. It shows the buffer symbol with a third terminal added, called three-state control. This control line is often referred to as the enable, output enable, chip enable, and chip select. The purpose of this type of buffer is to provide isolation between input and output when the three-state terminal is at logic zero.

If the control terminal is at logic zero, there is no output, neither high nor low, regardless of the signal applied to the input. If the three-state terminal is at logic 1, the output will be whatever is at the input terminal of the buffer. If the three-state terminal is logic zero, the output is an open circuit. A logic probe then connected at the output will indicate neither high nor low. The open-circuit output will be "floating:" that is, it is in a high-impedance condition. A VOM may indicate noisy or stray circuit voltages, but these will normally not affect a following circuit. There is also a three-state **inverter.** Its logic symbol is the same as that of the three-state buffer except that it has a NOT circle at its output. When the three-state terminal of the three-state inverter is at logic 1, the output is the opposite of the input. The output is logic 0 if the input is logic 1, or the output is logic 1 if the input is logic 0. If the three-state terminal is logic 0, there is no logic input. The output is in a high impedance state.

Flip Flops

Flip flops are logic circuits or devices that come under the general classification of sequential logic. That is, a change in logic state at one place in the circuit results in another change at another place in the circuit. In its simplest form, the flip flop consists of two interrelated gates. When the output of one gate is at logic 1, or enabled (or high), the output of the other gate is at logic 0 or disabled (or low). Conditions at the inputs of a flip flop determine what the output will be, and can cause the outputs to flip back and forth between two conditions.

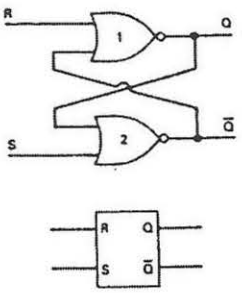
Set-Reset (or RS) Flip Flop

The set-reset, or RS flip flop is a basic form of flip flop, and an example made up of two NOR gates is shown in Figure 7-19. It is shown in both logic-symbol form and, as sometimes

seen, in block form. The two inputs are labeled S and R for set and reset respectively. The two outputs are indicated as Q and Q. Q and Q are always the opposite of each other if the circuit is operating properly. The table shows output conditions for each possible input condition. Note that the output of each NOR is criss-crossed back to the input of the other NOR.

Figure 7-19.

NOR TYPE RS FLIP FLOP



NOR R-S FLIP-FLOP			
R	S	Q	$\overline{Q}$
1	1	Illegal	
0	1	1	0
1	0	0	1
0	0	Unchanged	

The operation of the NOR RS flip flop is explained as follows: suppose logic 1 is at the R input and logic 0 at the S input. NOR gate 1 outputs a logic 0 to output Q. At the same time, this logic 0 crosses back to the input of NOR 2. The NOR 2 inputs are now both logic 0, so NOR 2 is not enabled. The $\overline{Q}$ output is at logic 1 (or high). In this condition – where Q output is logic 0 and its $\overline{Q}$ (or Q-not) output is logic 1, the flip flop is said to be reset.

For the opposite input condition, logic 0 at input R, and logic 1 at input S, NOR 2 has a logic 0 at its output and also sends a logic 0 to one input of NOR 1. With both NOR 1 inputs now logic 0, its output is logic 1. Thus, with logic 1 at the Q output and logic 0 at the Q-not output, the latch is set.

According to the table, the condition of logic 1 at both inputs is shown as being ambigious, or illegal, or undetermined. The outputs of both gates would be logic 0 in that case. The flip flop would not be able to serve its purpose, being confused, so that condition is to be avoided. Logic 0 at both inputs is also to be avoided as it would prevent any change in the outputs. Thus the outputs are shown as status quo – that is, the outputs would remain at whatever state they were in when logic 0 was applied to both the R and the S inputs.

The RS flip flop has the ability to store or hold onto a logic state. This is referred to as latching action, and the circuit is often called a latch. Its output, logic 1 at Q output and logic 0 at Q-not output, will not change unless S input is changed to logic 0 and R input becomes logic 1.

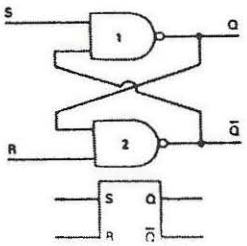
NAND RS Flip Flop

The circuit for the NAND type of RS flip flop is shown in Figure 7-20. Its operation is the same as that of the NOR RS latch just discussed with one exception; with R and S NAND-latch inputs both at logic 0, the output is ambiguous, or illegal, which is just the opposite for that of the NOR RS latch. Also, if both inputs of the NAND RS latch or NAND RS Flip Flop somehow become logic 1 at the same time, the Q and Q-not outputs both remain at whatever states they were in previously.

Figure 7-20.

NAND TYPE

RS FLIP FLOP



NAND R-S FLIP-FLOP			
R	S	Q	$\bar{Q}$
0	0	Illegal	
1	0	1	0
0	1	0	1
1	1	Unchanged	

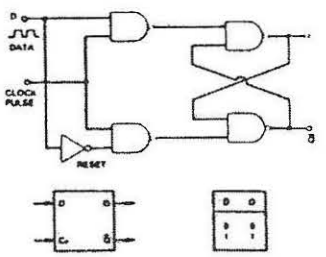
Data Flip Flop

A D-flip flop, or data flip flop, is shown in Figure 7-21 in both logic symbol and block form, along with its truth table. The data is applied to the D input. The logic level, 0 or 1, of the data is inverted by the NOT circuit and applied to the Reset input. Under these conditions, the operation of the D flip flop is as shown in the truth table. The Q output follows the D input. If a logic 0 at the D input occurs at the same time as the clock pulse, the Q output will be logic 0. Similarly, if D-input is logic 1 at the same time as a clock pulse, Q output will go to logic 1 or high.

Figure 7-21.

D OR DATA

FLIP FLOP

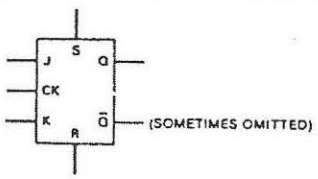


J-K Flip Flop

One of the most widely used flip flops is the J-K flip flop shown in Figure 7-22. The J-K flip flop has two data inputs (labeled J and K) and two data outputs labeled Q and $\overline{Q}$. It also has a clock input labeled CLK or trigger. The output produced by the J-K is dependent on the signals that are provided to the J and K. As you can see from the truth table, when J is high and K is low, Q is high; when J is low and K is high, Q is low; when J is high and K is high, Q toggles to the opposite state; when J is low and K is low, Q remains in the same state and is not affected by the input. While the J and K inputs determine the level of the output, the signal applied to the clock input determines when the output can change. Typically, the flip flop looks at, or latches, the J and K inputs when the signal applied to the clock input changes from low to high. The flip flop then applies the rules of the truth table to determine the conditions of the output. The output is changed on the high to low transition of the clock signal. Notice that the output will only change when the appropriate clock signal is applied.

The set or S and reset R inputs appear on some J-Ks and allow an external device to immediately affect the outputs regardless of the signals on the J and K inputs and/or the condition of the clock input. These direct control inputs are often used to initialize the J-K to a predetermined state.

Figure 7-22. J-K FLIP FLOP AND TRUTH TABLE
(Courtesy of Microprocessor Basics, Part 1 ICS-IN TEXT)



J-K FLIP-FLOP — TRUTH TABLE

MODE	INPUTS R	CK	J	K	OUTPUTS Q	Q̄
LOAD 0 (RESET)	1	1→0	0*	1*	0	1
*LOAD 1 (SET)	1	1→0	1*	0*	1	0
CLEAR	0	X	X	X	0	1
TOGGLE	1	1→0	1	1	1←→0	
HOLD	1	X	0	0	1 OR 0	

X = Don't Care
* = State just before clock transition (1 → 0)

Counter and Divider Circuits

You should be familiar with counter and divider circuits since it is likely you will run into at least one question on those. Flip flops are used for counter and divider operations, including J-K and D, or data flip flops as shown in Figure 7-23. The J-K flip flop can be wired to divide by two (toggle) whenever a pulse is delivered to the clock input line. Flip flops can be cascaded to divide by any power of two. For example, one flip flop can divide by two, two flip flops can divide by four (2^2), three can divide by 8 (2^3), and so on.

Other counting circuits you should known a little about include ripple counters, shift registers, ring counters, and BCD counters.

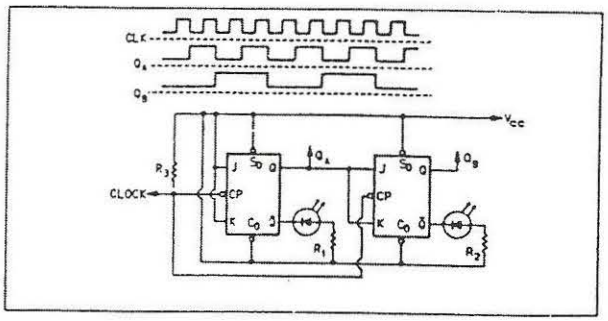


Figure 7-23. J-K USED AS A COUNTER CIRCUIT
(Courtesy of **Digital Microprocessor Course**. EIA/CEG)

Synchronous Counter

The J-K flip flop counter just described is referred to as a synchronous counter since it requires the simultaneous occurrence of two inputs in order to produce an output. The two signals were the logic high at the D input and the clock pulse. The requirement of having the synchronous signal (clock pulse) assures that the counter circuit is not triggered into false operation by glitches or other noise pulses. (A glitch is an unwanted signal of very short duration.)

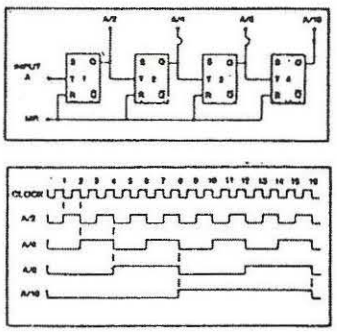


Figure 7-24. COUNTER AND WAVEFORMS
(Courtesy of **Applications of Logic Circuits**, ICS-INTEXT)

The asynchronous, or ripple, counter may be explained by referring to Figure 7-24, showing four R-S flip flops in cascade. The output of each R-S latch is connected to the T, or timing output of the next latch. The timing waveform is also shown in the figure. The clock pulse is the top waveform, A/8, shows two pulses for a division of 8, at the output of the third flip flop. Finally, the bottom waveform is a single pulse, a division of 16, indicated as A/16 at the output of the fourth flip flop.

Parity

In many digital circuits, a parity bit must be included to make a binary byte or other group of bits an authentic signal. (A bit is a binary logic 1 or 0; a byte is a group of eight binary bits.) Depending on the design of the circuit, a parity bit may be either logic 1 or logic 0. The technician should have an understanding of asynchronous serial communications.

Encoders and Decoders

Encoders and decoders are logic circuits that convert or translate from one digital system to another. For example, a decimal to BCD encoder would convert a decimal number to a binary-coded number. Another encoder example is one that converts binary or BCD signals into signals for operating a seven-segment decimal display.

Often, this type of decoder is part of an integrated circuit which includes a driver that provides the output needed for powering a seven-segment display.

Memory

You are likely to run into at least one question of electronic-circuit memories in your test. Memories may be classes as either static or dynamic, as far as their need for a continuing reapplication of energy to store memory contents is concerned. A static memory example is a flip flop. A static memory does NOT require a refresh signal in order to ensure that its memory contents do not fade away or discharge. A dynamic memory needs a refresh signal. An example is a capacitive type of memory which can discharge to the point where its memory contents are no longer usable. The capacitor or capacitors holding the charge or charges must periodically be refreshed or resupplied with charging energy.

Data access is much more rapid with dynamic memories, meaning data can be read into or read out from a dynamic memory much more quickly than with a static memory.

Computer memory may be classified as to whether it is volatile or nonvolatile. A volatile memory loses its contents if power fails or is switched off. Semiconductor memory that is volatile is called RAM. A non-volatile memory keeps its memory contents even if power is turned off. Examples are magnetic tape, floppy and hard disks, PROMS, ROMS, EPROMS, and EEPROMS.

Computer Memories

Some of the main types of computer memories that are essential to know about are the RAM, the ROM, the PROM, the EEROM, the EPROMS, and also magnetic tape and magnetic disk.

The RAM is a volatile memory – the letters RAM stand for Random Access Memory. Information can be written into and read out of this type of memory. ROM, meaning Read Only Memory, is a nonvolatile memory. Data stored in ROM stays there for continuous use. It is a permanent memory, although some types of ROM can be erased and reused. PROMs can be programmed only once. One ROM that can be erased and have new data programmed into it is EPROM, or Erasable Programmable ROM. With the EPROM, information originally stored can be erased with ultraviolet light and the memory can be reprogrammed. Removing an EPROM from a circuit board is inconvenient and often impractical, so another type of programmable

ROM was developed. This one is known as the EEPROM, meaning Electrically-Erasable Programmable Read Only Memory or EAROM (Electrically-Alterable Read Only Memory).

Substitution of Parts

In working with computer or logic circuits, be aware that some components are available that are claimed to be the equivalent of each other. In some cases, these can be directly interchanged and circuit performance will not suffer. In other cases, there could be a deterioration of performance. Generally speaking, you should use exact replacement parts wherever it is possible.

In particular, substitution between TTL and small-scale CMOS devices is not recommended, especially in logic circuits and where a clock signal is involved. Mixing them could produce either erroneous results or glitches due to clock edges not coinciding. TTL also requires more signal power for operation. TTL requires a regulated 5V supply for power; CMOS can operate on a range of supply voltages from 3V to 15V. Also to be avoided is substituting ECL devices for TTL and CMOS, because ECL operates from a –5V source.

Early MOS devices were very susceptible to damage due to static discharge. Touching a soldering iron to these circuits or handling them without a special grounding strap could destroy these devices. Later developments by manufacturers in buffering and isolating CMOS and MOSFET devices have greatly reduced static damage. However, some reasonable precautions should still be observed.

One important way that CMOS devices have been protected from damage due to spikes, glitches, or static discharge is to use a varistor or a zener diode across the inputs. The varistor, whose resistance decreases with voltage, acts to short-circuit sudden high voltage and potentially damaging signals.

Microprocessors

A microprocessor may be described as the control and processing portion of a small computer, microcomputer, or computer-like system. Microprocessors are typically built from large-scale integrated circuits that are usually of the MOS type. A microprocessor, often built on a single chip, usually is accompanied by other chips (ICs) that provide interfacing and control. Some microcomputer chips contain RAM and ROM. The ROM provides the permanent direction for operation of the microprocessor system. Also, the chip contains the ALU, or arithmetic logic unit. The ALU is capable of carrying out all the mathematical and logic operations required.

A microprocessor has three busses: the data bus, the address bus, and the control bus. The data bus carries information to and from the memory. The control bus carries signals from the microprocessor that indicate the kind of operation about to take place and provides for timing and external control. The data bus carries the instructions and the data bytes that are to be added,

subtracted, multiplied, divided, or to have many other operations performed on them. The address bus carries the location number or address of the device that will participate with the microprocessor in the current operation.

Microprocessors have found their way into a great number of everyday products that use electronic circuits for their operations. For example, microprocessors included in microwave ovens tell the oven what kind of heating cycle and how much pulsed power is needed to defrost a frozen roast, and how long is needed for this operation. Also, microprocessors are used in TVs. These include an EEPROM memory that contains channel-selection information. This information is kept in the EEPROM whether the TV is on or off. However, if the TV is later used in a location where other TV channels are available, the EEPROM can be erased and reprogrammed by the owner of the TV set. Microprocessors in TVs and in other equipment keep track of the day, date, time of day, and can display on the screen any of this information in addition to identifying what channel is being watched.

You should know what types of signals are present on microprocessor buses and lines. For example, a logic probe will show that the clock line carries a continuous stream of pulses. The data line carries seemingly random groups of pulses, as does the address bus. Some additional study of microprocessors will be of benefit in preparation for your test.

Multiplexer and Demultiplexer

Multiplexer and demultiplexer are terms that you might run into in a test. A multiplexer is a system for taking two or more data lines and combining their signals so they may then continue along a single line. The signals are combined either by converting them into separate frequencies, or by interleaving them into sequential time slots. A demultiplexer reverses the action of the multiplexer. It retrieves the signals from the multiplexed information and restores them to their respective separate channels.

Fan Out and Fan In

Fan-out is an expression used to designate the maximum number of inputs that can load the output of a logic device, or amplifier. For example, an AND circuit with a fan-out of eight can drive eight other inputs. To drive more input lines, additional buffers would be needed at the output. The expression fan-in designations the maximum number of input lines a device can accommodate. A fan-in of six means that six lines can be connected to the input before the load at the input becomes excessive.

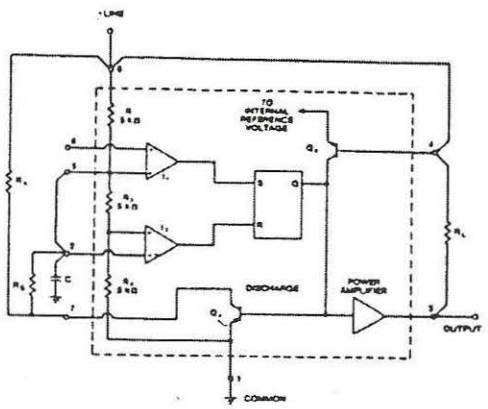
The 555 Timer

The 555 Timer is a single chip combining two comparators, an RS flip flop, a discharge transistor, and a power-out amplifier. It has many varied uses in electronics, especially where timing and triggering pulses are used. The circuit of a 555 Timer is shown in Figure 7-25. The dashed rectangle encloses the components making up the 555 Timer. Other components, outside

the dashed lines, are those that can be added to make use of the 555 Timer as an Astable (free-running) multivibrator.

Figure 7-25

555 Timer



The 555 Timer can also be adapted for use as a monostable or one-shot multivibrator, ramp generator, voltage controlled oscillator, and others. They are often used for the generation of clock pulses for logic circuits. This is a circuit requiring further study on your part since questions on the 555 Timer are found now and then in tests.

Differential Amplifier

A question on a differential amplifier may be included in your test. A differential amplifier, or diff amp, is an amplifier that has two inputs. If the signals applied to the inputs are equal, the output is zero. One important application of the differential amplifier is its use as the input stage of the operational amplifier.

The differential amplifier amplifies difference signals, but rejects common-mode signals. How well it rejects common-mode signals is indicated by a specification known as common-mode rejection ratio, or CMRR.

PRACTICE CET TEST QUESTIONS

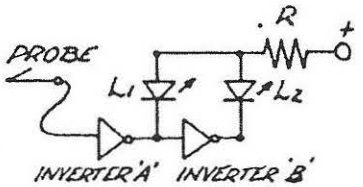
A certain counter is made with five flip flops. What is the highest number the counter could display?

A. 15_{10}
B. 24_{10}
C. 31_{10}
D. 32_{10}

Answer: C

The circuit in the figure shows a simple logic probe. When the input signal to the probe is a logic 0:

A. L1 is ON, L2 is OFF.
B. L1 is OFF, L2 is ON.
C. L1 and L2 are both OFF.
D. L1 and L2 are both ON.



Answer: B. Logic 0 from the probe becomes logic 1 at the cathode of L1, so L1 does not light. But logic 1 to inverter B becomes logic 0 at the L2 cathode, so L2 lights.

INSTRUMENTS

Be sure that when you are answering questions about instruments that you take into consideration any probe that is being used as described by the question. For example, if there is an X10 probe used in the measurement, then the **actual meter reading multiplied by ten gives the value of the voltage being probed.**

Another thing to remember is that the meter sensitivity, which is measured in ohms-per-volt, does not have anything to do with the number of ohms that the meter has when it is measuring a certain number of volts. For example, a typical question might ask: If a meter has a sensitivity of 20,000 ohms-per-volt, how much impedance does it have when it is measuring two volts?

A careless technician may answer this question with a value of 40,000 ohms-per-volt (2 x 20,000). That answer is absolutely wrong! The ohms-per-volt sensitivity is simply a measure of full scale deflection. Mathematically:

$$\text{Meter sensitivity (in ohms-per-volts)} = \frac{1}{\text{full scale deflection reading}}$$

SAMPLE CET TEST QUESTION

The full-scale deflection of a certain meter movement is 0.01 milliamperes. What is the ohms-per-volt sensitivity rating of that meter movement?

1) 0.01 ohms-per-volt
2) 100 ohms-per-volt
3) 20,000 ohms-per-volt
4) None of these answers is correct.

ANSWER: Choice (4) is correct. The real answer is 100,000 ohms-per-volt, which is obtained by taking the reciprocal of 0.01 milliamperes: $1 \div 0.00001 = 100{,}000$.

Be sure you understand the use of basic meters and the required polarity connection when using those meters. One example is the ammeter. It must be connected in such a way that the electron current flows through it from its negative terminal to its positive terminal. Therefore, it has to be connected into the circuit with a positive terminal of the ammeter looking toward the positive terminal of the source of current.

Obviously, you must never connect an ammeter across a voltage source! Ammeters (and milliameters and microammeters) are the ammeter looking toward the positive terminal of the source of current.

Obviously, you must never connect an ammeter across a voltage source! Ammeters (and milliammeters and and microammeters) are the basic meter movement in many other types of meters in use today.

SAMPLE CET TEST QUESTION

Consider the circuit of Figure 8-1 in which an ammeter is connected in series with a resistor. This connection will convert the ammeter to:

Figure 8-1

1) A voltmeter.
2) A wattmeter.
3) An ohmmeter.
4) None of these answers is correct.

ANSWER: Choice (1) is correct. An ammeter in series with a resistor makes a voltmeter. The resistor in this case is called a **multiplier.** In most applications a microammeter or milliammeter would be preferred in order to make the voltmeter more sensitive.

A resistor may be connected in parallel with a microammeter to convert it to an ammeter or milliammeter. In that case the resistor is called a **shunt.**

The oscilloscope is probably the most versatile instrument available to technicians. It can be used for:

- Measuring D-C voltages or D-C currents
- Measuring A-C voltages or A-C currents
- Measuring the phase between two voltages
- Measuring the frequency of any waveform
- Measuring the amount of time elapsed between two events (such as the start and end of a cycle)
- Making qualitative measurements such as in waveform analysis

Remember that in order to measure current with an oscilloscope, it is only necessary to put a very small resistance value in series with the current being measured. Then, the scope is used to measure the voltage and the current are numerically equal. This greatly simplifies using the scope for current measurement.

There is an important precaution to be observed when making voltage (or current) measurements with an oscilloscope. Remember that the scope gives **peak-to-peak values!** (If you want the RMS value of a peak-to-peak sinusoidal waveform, you have to divide the peak-to-peak value by two, and then multiply by 0.707.

Another precaution that must be taken is that RMS **values can be calculated by multiplying by 0.707 ONLY if the waveform is a pure sinusoid.** Any other waveform will have a different RMS value, and you cannot find the RMS value by multiplying its peak value by 0.707!

Likewise, you cannot find the average value of a non-sinusoidal waveform by multiplying its peak value by 0.636.

It is very desirable that the instrument used for measuring voltage – whether it is an oscilloscope or a meter – has a very high input impedance so the meter will not draw power (or current) from the circuit being measured. This is one of the advantages of an FET voltmeter over some bipolar transistor voltmeters: they have a very high input impedance. In the earlier days of electronics a vacuum-tube

voltmeter accomplished the same high impedance measurements that are now obtained with an FET meter.

Digital meters use seven-segment displays such as the type shown in Figure 8-2. These segments may contain LED's or some gaseous illuminator such as neon. There are also cases where the segments are lighted by filament-type bulbs. In any case, the numbers are made by lighting various segments in combination.

There is a special circuit, called a **decoder,** which can be used to convert a binary number into a decimal number for display. Decoders may be separate integrated circuits, but more often they are built into another integrated circuit called a **decoder/driver.** Use of the decoder/driver is shown in Figure 8-3.

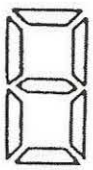


Figure 8-2

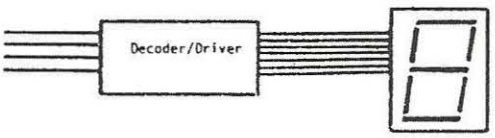


Figure 8-3

Parallax Error

When reading the value indicated by the pointer of an analog meter, it is important to have your eye directly over the pointer in order to get the most accurate reading. If your eye is located a little to the right of directly above, it will appear that the pointer is a little to the left of its real position. Or, if your eye is located a little to the left, it will appear that the pointer is a little to the right of its real position.

Some analog meters have a mirrored insert on the scale which helps to avoid parallax error. To ensure that the reading you are taking is as accurate as possible, position your eye directly over the pointer. Then, if necessary, move your head slightly to the left or right, as required to make the pointer and the pointer image in the mirror coincide.

Meters for Testing and Troubleshooting

Give some extra study, aside from what is covered in this guide, to the features, advantages, and disadvantages of the various types of meters. Compare the input impedance, loading effect, accuracy, and usefulness of VOMS, electronic meters, digital voltmeters, analog meters, and so on. Know how the use of a particular instrument affects the accuracy of the measurement you are making.

Some tests include a question on interpreting the value indicated by a pointer on the scale of an analog meter. It would be to your advantage to look over the different scales on a multipurpose meter.

Logic Probes and Other Instruments

The logic probe is an important instrument in dealing with logic circuit and other pulse and digital circuits. In digital circuits, the logic probe uses three LEDs to indicate logic high, logic low, and the presence of a stream of pulses. It does this by illuminating different LEDs. Some logic probes are designed for TTL circuits, some for CMOS circuits, and some are switchable. A logic probe designed for use only in TTL circuits (which are always 5 V circuits) should not be used in a CMOS circuit, which could be powered at a voltage of up to 15 V. A logic probe cannot measure voltages like an analog or digital meter.

could be powered at a voltage of up to 15 V. A logic probe cannot measure voltages like an analog or digital meter.

A logic pulser is another instrument designed for use in logic circuits. It can generate a single pulse at a time, or a stream of pulses.

A logic analyzer is a rather sophisticated instrument. It can display a number of logic signals at the same time, and it can also generate pulses to provide an input to a logic system; it can then follow the paths of the pulses through the system.

A breakout box is a special device that is useful in troubleshooting logic circuits and other systems where a number of signal and control cable lines enter and leave a computer or microprocessor or other equipment. Usually cables connect to such equipment by means of plugs. It is normally hard or impossible to get at the individual cable terminals with a meter, oscilloscope, or logic probe. To use a breakout box, the cable plug is disconnected from the equipment and plugged into the breakout box. The breakout box has a cable and plug which is unplugged into the equipment. The result is that the cable circuit is restored, but, inside the box, each of the conductors is brought to a test terminal. The terminals are easily accessible for testing and measuring.

Triggered and Dual-Trace Oscilloscopes

Triggered and dual-trace oscilloscopes offer important advantages when working with pulse and digital circuits. Know how to measure the duration of a pulse, its amplitude, rise time, delay, and frequency. Also, keep in mind that if you are using an oscilloscope with an X10 probe, the amplitude of the pulse you are measuring is 10 times what the oscilloscope indicates. Remember the oscilloscope has high input impedance.

But, in some cases in dealing with digital signals, a logic probe will be preferable to the oscilloscope. In particular, if there is a relatively long time between recurring narrow pulses, the narrow pulses might not show up on the oscilloscope. A logic probe will indicate the presence of these narrow pulses.

When measuring a very low-amplitude AC signal that's riding on a higher-value DC signal, you should know that the scope vertical-input should be switched to AC color. Then you can turn up the vertical gain of the scope to examine the AC signal without the DC voltage being a problem.

A big advantage of the triggered scope over the recurring-sweep scope is that the triggered scope makes it convenient to examine pulse edges, rise time, pulse width, and pulse repetition rate. Also, a triggered scope holds the display steadier when there is a slight shift in frequency or amplitude.

A dual trace scope provides for looking at two different signals at the same time, as in Figure 8-4, or at the same signal at two different circuits in the same equipment. In the figure, one pulse is delayed 5 microseconds in comparison with the original.

Figure 8-4 Display on Dual-Trace Scope Shows Pulse Delay

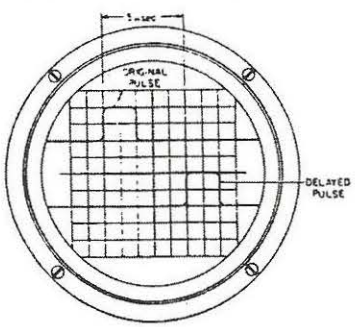
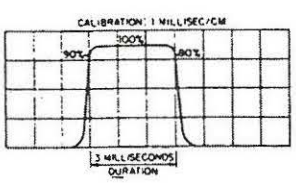
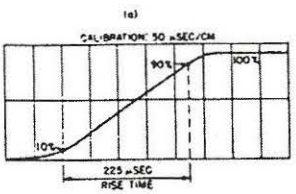


Figure 8-5

Measurement of Pulse Width



Measurement of Rise Time



Oscilloscope Controls

This part of the Study Guide provides a review of the important controls of a typical dual-trace oscilloscope.

In this discussion, the two channels of the oscilloscope are referred to as CH-A (for Channel A or CH-B for Channel B.

This review may be helpful to you in case you have not used a dual-trace oscilloscope, or any oscilloscope. In some cases it may be necessary only to describe a control for Ch-A if the control for CH-B serves a corresponding purpose

Figure 8-6 shows the front of a recent dual-trace oscilloscope. Some oscilloscopes are more elaborate than this one, some are less elaborate. Dual trace means that the oscilloscope provides two traces of different signals or two traces of a the same signal in different parts of the same equipment or circuit. By displaying two traces, signals can be compared, or the performance of a circuit on a signal can be examined.

Preparing the Oscilloscope

1. Prior to any kind of operation of the instrument

(a) Set the POWER switch to OFF (14)
(b) Turn three POSITION controls to midposition (6. 7. 23)
(c) Turn INTENSITY control to midpositon (21).
(d) Push the PULL 5X control for normal (7)
(e) Pull TRIGGERING LEVEL control for AUTO (13)
(f) The rest of the controls remain at any position for normal operation.
(g) Check the line voltage.

2. Connect one end of the AC line cable into the rear panel of the instrument, and plug the other end into an AC power outlet.

3. Turn the POWER (14) on. After about 20 seconds, trace lines appear on the screen. If no trace lines appear, turn the INTENSITY (21) control clockwise until trace lines are easily observed.

4. Adjust FOCUS (20) and INTENSITY (21) for clear trace lines

5. Readjust Vertical POSITION (6,23) controls and Horizontal POSITION (7) control to center the display.

6. If available, connect at 10:1 probe to INPUT CH-A (1) and hook the tip of the probe to CAL

Measurement of pulse width and rise time are shown in Figure 8-5. This measurement can be made with either a single-trace triggered scope, or with one of the channels of a dual-trace triggered scope. The upper display shows that the pulse width, measured between the 90% amplitude point on the leading edge of the scope and the 90% amplitude point on the trailing edge is 3 milliseconds. The display occupies three divisions, and each division is equal to 1 millisecond. In the lower display, the leading edge of the same pulse has been stretched out and the calibration is now 50 microseconds per centimeter. Rise time for a pulse is measured between the 10% and 90% amplitude points. For the pulse shown, 4.5 divisions or centimeters are shown for the rise time measurement. The rise time is therefore

50 microseconds per division x 4.5 divisions, or 225 microseconds

Review the use of the oscilloscope for measurement of voltage amplitudes. An oscilloscope can be calibrated for a certain number of volts per vertical division or centimeter.l If the preceding illustration showing measurement of pulse width was calibrated for 10 volts per vertical division, the pulse displayed would have an amplitude of about 35 V.

Keep in mind that an oscilloscope shows peak-to-peak amplitude. If you are displaying a sine-wave AC signal, in order to convert is peak-to-peak amplitude, it is necessary to multiply the peak-to-peak amplitude by 0.353 to know the RMS (root-mean square) value. Or, if you know that a certain sine-wave AC signal is, say, 10 V RMS, you multiply that value by 2.828 to know what the displayed peak-to-peak amplitude should be on the scope. In this case, for a 10 V RMS sine-wave voltage, it should measure 10 x 2.828, or 28.28 V peak-to-peak.

You should know that the Z-axis input of a scope can be used to control the intensity of the display, or to modulate or chop the display into segments.

In video troubleshooting, pulse width is measured between 90% amplitude points. In digital circuits, measurement is usually between 50% amplitude points, as is shown in Figure 8-6.

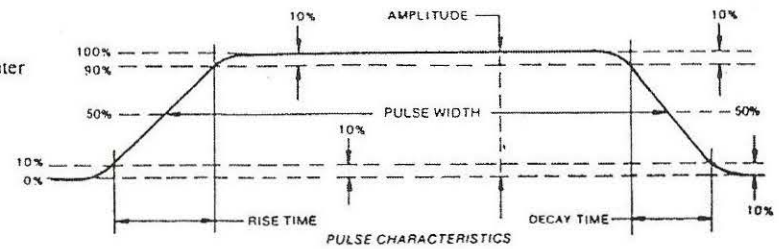


Figure 8-6 Pulse Width in Logic, Digital, and Computer Circuit is Usually Measured Between 50%-Amplitude Points

0.5Vp-p (11) output.

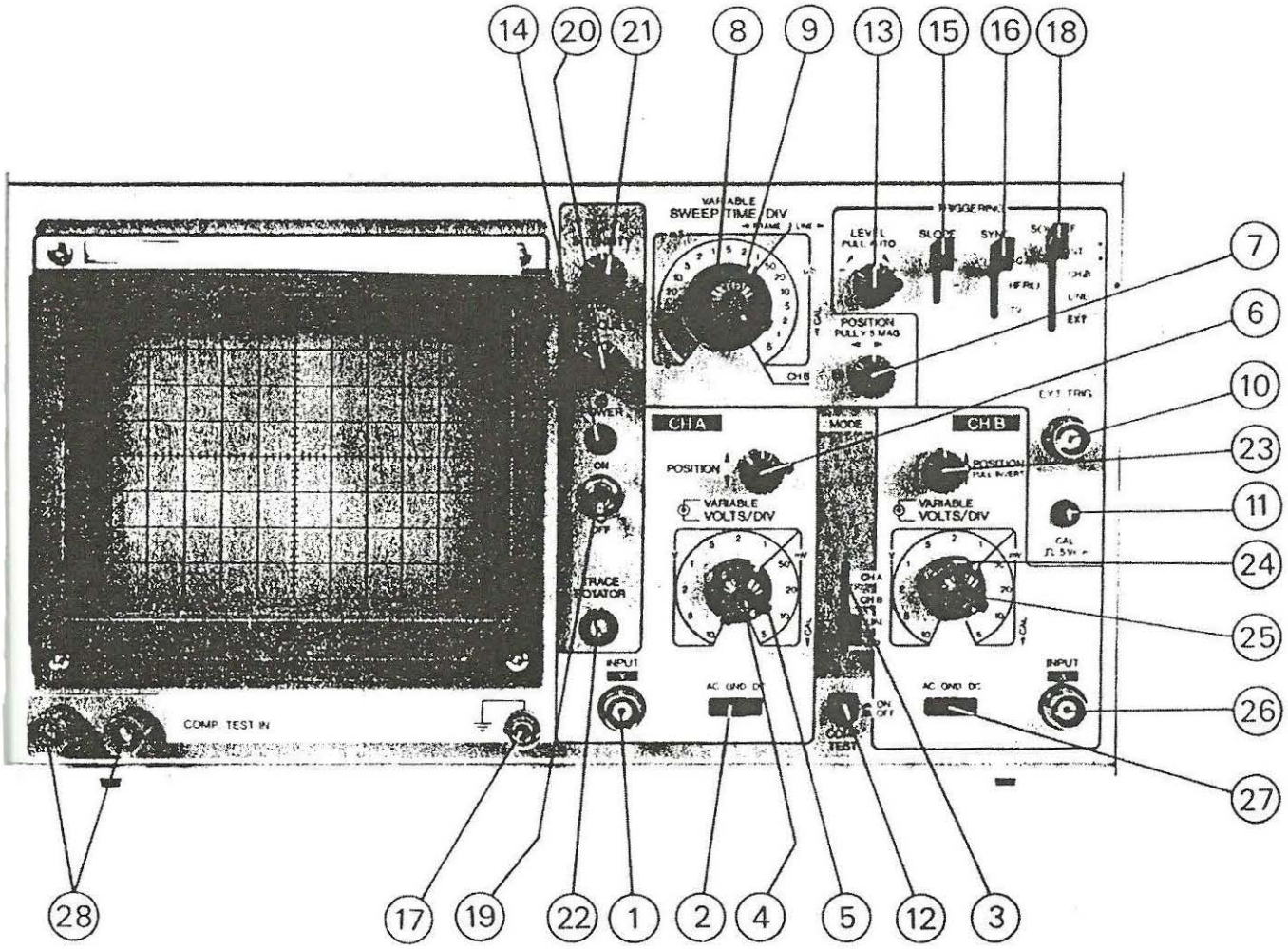


Figure 8-6

7. Rotate CH-A Vertical Attenuator VOLTS/DIV (5) switch to 10mV/DIV and turn the VARIABLE (4) on the same axis clockwise to detent. Turn the TRIGGERING SOURCE (18) to Ch-A. Then a square wave of 5 divisions should be displayed on the screen.

8. If the square wave is distorted, adjust the trimmer of the probe until it becomes a good square wave.

9. Remove the probe tip from the CAL output. Now the oscilloscope is ready for use.

Controls and Indications

VERTICAL

The numbers preceding the controls are the same numbers that appear in the illustration of Figure 8-6,

(1) VERTICAL INPUT
Vertical Input for CH-A.

(2) AC-GND-DC
Vertical Input coupling for CH-A. In the AC position, the DC component of the signal is blocked by a capacitor. In the GND position, the input terminal opens and the input of the internal amplifier is grounded. In the DC position, the input terminal is direetly connected to the amplifier and all components of the input signal are displayed.

(3) MODE
IN CH-A of the Mode switch, waveforms of CH-A are displayed.
In CH-B of the mode switch, waveforms of CH-B are displayed
In the DUAL position of the Mode switch, in the range from 0.5sec/DIV up to l msec/DIV, both channels are chopped at about 200 kHz.
In the range from 0.5msec/DIV up to 0,5microsec/DIV, the channels are switched alternately.
In the ADD position of the MODE switch, CH-A and CH-B signals are added. By pulling (23) PULL INVERT,SUB Mode is obtained.

(4) VOLTS/DIV VARIABLE
Waveform amplitude for CH-A

(5) VOLTS/DIV
Vertical step attenuator for CH-A. The scale is graduated in voltage per "DIV" of CRT Screen area.
Calibrate voltage is indicated when VARIABLE (4) is turned fully clockwise.
Selectable in 10 calibrated ranges from 0.5mv/DIV to 5V/DIV.

(6) VERTICAL POSITION
Vertical position adjuster for CH-A.

HORIZONTAL, SWEEP, AND TRIGGERING

(7) HORIZONTAL POSITION and PULL 5X MAG
Horizontal position adjuster. When pulled, SWEEP TIME (9) is magnified by 5.

(8) SWEEP TIME/DIV
Horizontal sweep time selector. It selects sweep time of 0.5 microsec/DIV to 0.5sec/DIV in 19 calibrated steps. X-Y operation is possible by turning the knob fully clockwise to CH-B.

(9) SWEEP TIME/DIV VARIABLE

(10) EXT. TRIG

Input for external triggering signal.

(11) CAL

Calibration voltage terminal. Calibration voltage is 0.5v/p-p at about 1 kHz square wave.

(12) COMP. TEST

Switch to change from component to oscilloscope tester. For component testing (8) SWEEP TIME/DIV must be set to CH-B for X-Y position.

(13) TRIGGERING LEVEL

LEVEL control adjusts sync phase to determine the starting point of sweep on the slope of displayed waveform.

PULL AUTO. By Pulling the LEVEL toward you, auto-sweep is affected, the sweep is set in free-running state even when no input signal applied, with trace line displayed on CRT..

With trigger signal, triggered sweep is affected where sync level is adjustable. When sync level is deviated, the sweep is set in free-running state.

(14) POWER ON LAMP

(15) SLOPE +, -.

Sync slope polarity is affected.

(16) SYNC

Sync mode selector switch.

AC: For normal operation. In this mode signal is directly fed to the sync circuit.

HF REJ: Low-pass filter, cuts off RF components of the sync signal.

TV: TV or Video composite signals are easily triggered. SWEEP TIME\DIV selects TV-V (50 microsec~0.1 msec) or TV-H (50 microsec~0.2 microsec)

(17) GND

Ground terminal.

(18) SOURCE

Sync signal selector

INT: CH-A and CH-B signals are added on for triggering.

CH-A: Sync signal for triggering comes only from CH-A.But, when in single sweep, the channel selected by MODE has priority.

Ch-B: Signal from CH-B. The rest is the same as CH-A.

LINE: AC powerline waveform is used as the sync signal.

EXT: The signal hooked into EXT TRIG (10) becomes the sync signal source.

(19) POWER SWITCH
Turns the power on and off.

(20) FOCUS
Focus control to obtain optimum waveform sharpness.

(21) INTENSITY
Adjusts brightness of the waveform for easiest viewing.

(22) TRACE ROTATOR
Magnetics of earth affect the trace line. Rotate this with a screwdriver for proper trace line.

CHANNEL B, VERTICAL

(23) CH-B PORTION, PULL INVERT
CH-B vertical position control. When pulled, the CH-B vertical polarity is inverted. This facilitates SUB MODE measurement at ADD MODE.

(24) VOLTS\DIV
Vertical attenuator for CH-B.

(25) VARIABLE
Variable control for CH-B.

(26) VERTICAL INPUT
Vertical input for CH-B

(27) AC-GND-DC
Same as (2)

(28) COMPONENT TEST IN
Terminals to connect a component or lead wires to a component under test.

(29) Z AXIS
This terminal is on the rear panel, and is used in some cases for modulating the trace.

TESTS AND MEASUREMENTS

The impedance of a voltmeter, or other measuring instrument, should be at least ten times greater than the impedance across where the measurement is made. For example, an automatic volume control (AVC) circuit in a radio is usually a very high-impedance circuit. In fact the impedance in that circuit may be several megohms. If you connect a volt-ohm-milliammeter with an impedance of 100,000 ohms between the AVC circuit and common, you will NOT be able to measure the AVC voltage. The reason is that the meter will act like a short circuit.

An important precaution when making measurements with an ohmmeter is to remember that an ohmmeter applies voltage to the circuit being measured. If the meter voltage is enough to turn on a transistor, or forward bias a diode in the circuit, then you may get an erroneous resistance reading.

SAMPLE CET TEST QUESTION

In the circuit of Figure 9-1 the resistance of 'R' is to be measured. One way to do this is to use a meter that has a low-power ohms scale. That prevents the transistor from being turned on by the ohmmeter voltage. If a low-power ohms scale is not available, you could make this measurement by connecting the:

1) Negative side of the ohmmeter to the base side of the resistor and positive side of the ohmmeter to common.
2) Positive side of the ohmmeter to the base side of the resistor and negative side of the ohmmeter to common.

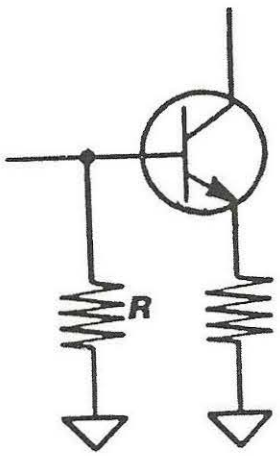


Figure 9-1

ANSWER: Choice (1) is correct. By using the negative side of the ohmmeter at the base and the positive side at common the ohmmeter voltage will reverse bias the emitter-to-base junction of the NPN transistor. That will prevent current from flowing in the base circuit during the measurement. If current were allowed to flow in the base circuit, it would be in parallel with the current through the resistor, and an incorrect resistance value would be displayed. (In fact the displayed value would be lower than the true value.)

An important type of question for you to be able to answer is: What is the frequency of a certain oscilloscope display when the time for one cycle is known? The equation for obtaining the answer is:

$$f = \frac{1}{T}$$

(T is known as the **period** of the wave, or, the time for one cycle. **The reciprocal of the time for one cycle is the frequency of that waveform.**)

One example was given in a previous chapter. Here is another example.

SAMPLE CET TEST QUESTION

In Figure 9-2 what is the frequency of the waveform being displayed?

1) 50,000 hertz
2) 100,000 hertz
3) 150,000 hertz
4) None of these answers is correct.

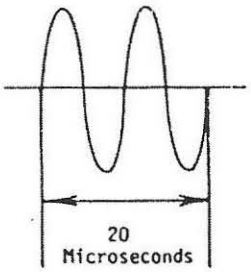


Figure 9-2

ANSWER: Choice (2) is correct. The time for two cycles on the display is 20 microseconds. One cycle has only a time length of 10 microseconds. The reciprocal of 10 microseconds is 100,000 hertz.

Standing wave meters are used for evaluating impedance matches on transmission lines. A question asked at one time was: if you took a piece of transmission line and cut it in half, what would its impedance value be? Many technicians answered that the impedance would be cut in half. That is obviously not correct. Cutting the transmission line into smaller pieces does not change its impedance. Therefore, if you took a piece of 300 ohm transmission line and cut it in half, both pieces would be 300 ohm lines. The question is not used extensively any more but you may run across it.

One enterprising technician claimed the question couldn't be answered because the test questions didn't say to cut across the line. So, he imagined it being cut lengthwise.

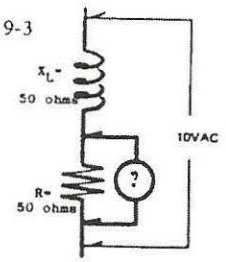
Another question that has been used extensively in the past was the purpose of a thermocouple ammeter. Thermocouple ammeters are used for measuring true RMS value. The way they work is that the current being measured is caused to flow through and heat a piece of wire. A thermocouple, touching that wire, is heated by the current. It produces a voltage that is proportional to the heat of the current. That voltage is measured by a small voltmeter which is calibrated to read current. Thermocouple meters display true RMS values of AC waveforms regardless of their waveshape.

Questions of the following type have been missed by many technicians. They are mostly questions that deal with the understanding of A-C circuits, but they are also questions that deal with measurements.

SAMPLE CET TEST QUESTION

What is the voltmeter reading for the circuit shown in Figure 9-3?

Figure 9-3



1) 5 volts

2) Slightly over 7 volts

3) 10 volts

4) The answer cannot be determined

ANSWER: The correct answer is slightly over 7 volts (2). At first it looks like the voltages will divide equally to produce 5 volts across the inductor and across the resistor. However, **those components have phasor relationships which are in quadrature.** That simply means that the voltage phasor will be at right angles to one another, and **the 10 volts is the resultant of the two phasor voltages.** You can see this by drawing a simple triangle as shown in Figure 9-4.

Another type of measurement question that is frequently missed by technicians is shown in Figure 9-5.

SAMPLE CET TEST QUESTION

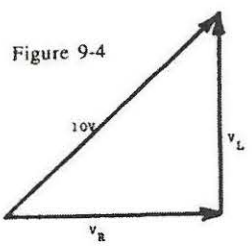
The purpose of the circuit in Figure 9-5 is to measure the leakage current of the capacitor. What type of meter should be used for this measurement?

1) An ammeter

2) A voltmeter

ANSWER: Choice (2) is correct. If you connected an ammeter in that circuit, it would likely be burned out by the high charging current of the capacitor. But the question is sometimes asked: can a voltmeter be used for leakage CURRENT? The answer is YES. Technicians with experience can determine if the leakage current is excessive simply by measuring the deflection on the voltmeter. The series multiplier in the voltmeter serves to limit the charging and leakage current. (If you know the value of the series multiplier resistor, you can calculate the leakage current and compute your answers with the allowable leakage current.)

Figure 9-4



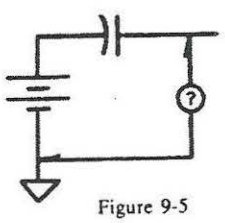
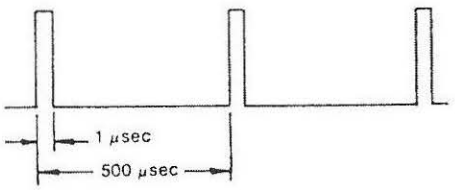


Figure 9-5

Duty Cycle

An important term often found when discussing or dealing with pulse circuits is **duty cycle.** This quantity, expressed as a percentage, tells how much of the time a pulse exists in comparison with the total time from one pulse to the next. For example, in Figure 9-6, a positive-going pulse has a pulse width of 1 microsecond, and the time between the beginning of one pulse and the next is shown as 500 microseconds.

Figure 9-6 Example of Pulse Specifications For Calculating Duty Cycle



The formula for calculating duty cycle is

$$\% \text{ duty cycle} = \frac{PW}{T} \times 100$$

where PW = pulse width
T = period of each cycle of pulse waveform

For the pulse shown in Figure 9-6

$$\% \text{ duty cycle} = \frac{1}{500} \times 100$$

$$= 0.2\%$$

PRACTICE CET TEST QUESTION

A certain pulse measures 10 milliseconds in width, and has a period of 50 milliseconds. The duty cycle is

1) 20%
2) 5%

ANSWER: (1) Duty cycle $= \frac{10}{50} \times 100 = 0.2 \times 100 = 20\%$

TROUBLESHOOTING AND NETWORK ANALYSIS

There are some direct coupled bipolar transistor amplifiers that you should NOT test by the base-emitter short method. The circuit in Figure 10-1 is only a simple circuit of this type. In some complex circuits, a base-emitter short can cause high DC currents which may enable protection circuits or damage components and/or loads in circuits which are not protected.

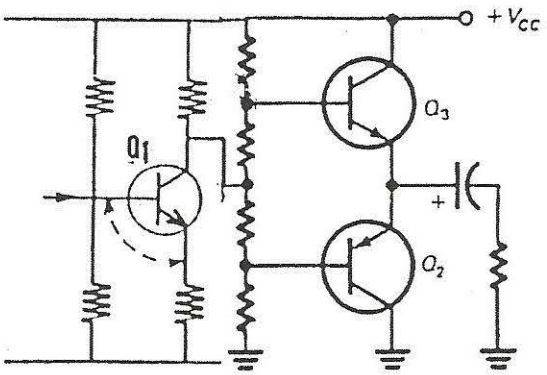


Figure 10-1

SAMPLE QUESTION

What polarity of D-C voltage should there be at point 'X' in Figure 10-2?

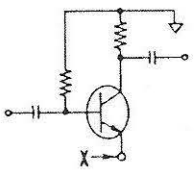


Figure 10-2

ANSWER: The voltage at point 'X' should be negative with respect to common. This type of question (with other types of amplifying devices) is used on many CET tests.

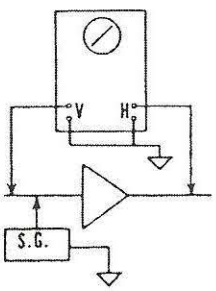


Figure 10-3

The basic test set up as shown in Figure 10-3 is used for checking both nonlinear and phase shift distortion. You will recognize this as a test set up that will produce a lissajous pattern on the oscilloscope screen. If the amplifier is linear the lissajous pattern will be a straight line. If the line is not straight it indicates that some form of an amplitude distortion is taking place.

Also, if an ellipse is obtained rather than a straight line it indicates that there is some phase shift distortion present.

The test set up in Figure 10-3 is for making **qualitative** measurements. They require the experience of a technician to interpret the significance of the phase shift or amplitude distortion being measured. A quantitative test gives a number value for comparison with the expected value. A voltmeter is used for a quantitative test.

The square wave test is another qualitative method of quickly evaluating amplifiers. In this test a square wave is applied to the input of the amplifier under construction. The output of the amplifier is observed on an oscilloscope. As a general rule, high-frequency distortion will cause the rounding off of the vertical parts of the square wave; and, low-frequency distortion causes a tilt (or rounding) of the horizontal portions of the square wave. By observing the square wave output of the amplifier on an oscilloscope a technician can quickly determine if there is any significant frequency distortion in the amplifier under test.

A disadvantage of the square wave test is that it cannot show distortion produced by clipping. This is a form of **nonlinear distortion.** If it occurs during a square wave test the only observable result would be a very nicely shaped square wave.

To avoid this problem, some technicians use what is known as a **triangular wave test.** A triangular wave applied to an amplifier can be used to determine low-frequency and high-frequency distortion as well as amplitude distortion. The problem with the triangular wave test is that is harder to interpret, so it requires more experience.

Pure sine waves are not normally used for testing amplifiers. One exception is to test for crossover distortion in push-pull or complimentary amplifiers.

As part of the Troubleshooting section of the CET test you will be expected to make measurements of rise time, frequency and voltage from an oscilloscope display. You are also expected to understand the basic types of probes – especially oscilloscope probes.

Remember that for high-frequency measurements of intermediate and RF frequencies, it is common practice to use demodulator probes. In a demodulator probe a detector and RC combination is used to convert the IF (or RF) signal to an observable audio modulation signal. The detector circuit removes the IF or RF variations of the signal.

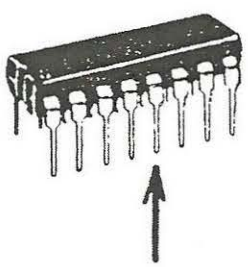
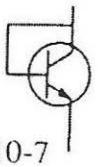


Figure 10-4

1) The transistor will be destroyed by the connection
2) The transistor can be used as a diode when it is connected this way.



ANSWER: Choice (2) is correct. Figure 10-7

A D-C voltmeter is connected across a pure sine wave voltage source as shown in Figure 10-8. The meter will display:

1) The RMS value of the voltage.
2) The peak value of the voltage.
3) One-half the peak value of the wave.
4) Zero volts.

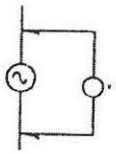


Figure 10-8

ANSWER: The meter will display the full-cycle average value. Choice (4) is correct.

The D-C voltmeter in Figure 10-9 should read:

1) 6V.
2) 12V.
3) 13.07V.
4) Approximately 0.7V.

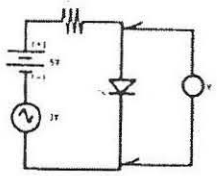


Figure 10-9

ANSWER: Choice (4) is correct. The diode is forward biased so it conducts at all times. The voltage across the conducting diode is nearly zero volts.

The circuit marked R and C in Figure 10-10 forms a

1) Low-frequency compensating circuit
2) Decoupling filter
3) Can't tell

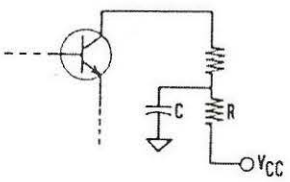


Figure 10-10

ANSWER: Choice (3) is correct. You need to have the values to tell the application because both circuits have the same configuration. If it is a low-frequency compensating network, then R is a high resistance about equal to R_L and C is also a high value (0.1μ is typical). For a decoupling filter, C is usually small; and, R is usually less than 100 ohms.

Hot Chassis Equipment

Some electronic equipment is manufactured without the use of an isolation type of power transformer. Equipment of that type is operated directly from the power line. One side of the AC line is connected directly or indirectly to the chassis of the equipment. Examples of such equipment are AC/DC TVs, radios, and stereos. If the AC line cord is plugged into a receptacle in such a way that the hot side of the AC line is the one that then goes to the chassis of the radio or other equipment, a dangerous condition exists. Someone touching the chassis of the set and simultaneously touching a ground point, such as a water pipe, could receive a hazardous shock.

Some plugs on line cords of transformerless equipment are polarized – one plug slightly wider than the other – so the plug can be inserted in the receptacle only the "safe" way.

When working on transformerless and hot chassis equipment, an isolation transformer should be used. The equipment being worked on is plugged into the isolation transformer, and the isolation transformer is plugged into the power line. This isolates both sides of the AC line from the equipment chassis. Some technicians use an isolation transformer when working on equipment of any kind, just to be extra safe.

Wrong Transistor Connections

Some transistor questions relate to things that might go wrong during troubleshooting. For example, what happens if an NPN transistor is replaced with a PNP transistor by mistake? Of course, the circuit would not work, and possibly the transistor would be destroyed. What happens if a transistor is taken out of a circuit, and then plugged in again, but in reverse with regard to collector and emitter. In this case, the transistor could work, but with reduced gain.

What happens if the emitter and base terminals are interchanged? It's possible that this one cannot be answered without knowing more about the rest of the circuit: what kind of bias, how is the transistor being used, and so on.

Diode and Bipolar Transistor Tests

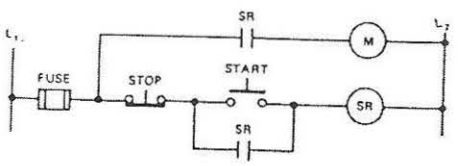
A technician should know how to check a diode using a VOM. A resistance measurement across the diode should measure a relatively low value of ohms with the meter leads in one position. Reversing the meter leads should give a considerably higher reading.

For testing a bipolar transistor, checking the emitter-collector resistance should give a high resistance reading for both connections of the meter leads. But the emitter-base junction and the collector-base junction should both give a low resistance reading for one connection of the meter leads, and a high resistance reading for the other or reverse connection of the leads.

Ladder Diagrams

A type of diagram called a **ladder diagram** is used to describe control circuitry commonly found in heavy industry. While many of these processes are controlled with programmable controllers, as a future electronics technician employed in manufacturing, you will encounter a ladder diagram. You might also find one in your test.

Figure 10-11



LADDER DIAGRAM

SR is not a capacitor. It is a normally open contact.

An example of a ladder diagram is shown in Figure 10-11. A ladder diagram is so called because the two AC lines powering the electrical system are usually drawn vertically (L_1 and L_2 in the diagram), one on each side of the diagram, like two sides of a ladder. The circuits powered by AC are connected across the line.

In the diagram shown, there is a fuse connected in series with two circuits in parallel. The upper circuit includes the contacts of a start relay (SR) and a motor (M). The lower circuit includes a STOP switch, a START switch with SR contacts across the switch, and the coil of the START relay. Pushing the start switch closes the SR contacts in series with the motor, starting the motor. The other SR contacts also close and are kept closed, even after the start switch is released, by the holding action of the relay coil.

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